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ABSTRACT

One of a series of training manuals prepared for enlisted personnel in the Navy and Naval Reserve, this self-study program is designed to enable the electrician's mate to prepare himself for the increased responsibilities of a senior petty officer with ability to operate, maintain, and repair voltage and frequency regulating equipment transistorized control devices, automatic degaussing systems, no-break power supplies, and electrohydraulic load-sensing governors. Contents include an 11-chapter text followed by a subject index, occupational standards, and the associated nonresident career course (five reading assignments with technical questions based on the occupational standards in the respective assignment). Chapter headings are (1) Career Program, (2) Safety, (3) Voltage and Frequency Regulation, (4) Transistorized Control Devices, (5) Automatic Degaussing, (6) Gyrocompasses, (7) No Break Power Supplies, (8) Electrohydraulic Load-Sensing Speed Governors, (9) Engineering Casualty Control, (10) Maintenance Administration, and (11) Visual Landing Aids (VLA). The appendixes include temperature and metric conversion tables. (HD)

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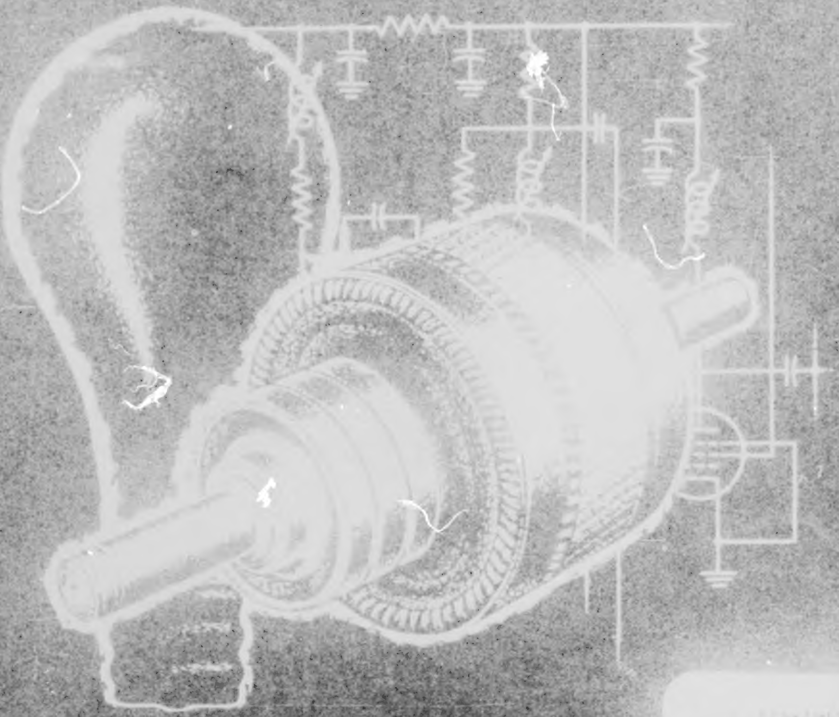

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ELECTRICIAN'S MATE 3 & 2

NAVAL EDUCATION AND TRAINING COMMAND

RATE TRAINING MANUAL
AND NONRESIDENT CAREER COURSE

NAVEDTRA 10547-D

CE 008 181

PREFACE

This Rate Training Manual and Nonresident Career Course (RTM/NRCC) form a self-study program that will enable the ambitious Electrician's Mate to prepare himself for the increased responsibilities of a senior petty officer. Among these responsibilities are the abilities to operate, maintain, and repair voltage and frequency regulating equipment, transistorized control devices, automatic degaussing systems, no-break power supplies and electrohydraulic load-sensing governors. In addition, he must prepare himself to administer maintenance and safety programs as well as to teach engineering casualty control.

This RTM/NRCC package is designed for individual study and not formal classroom instruction. The RTM presents subject matter that relates directly to the occupational qualifications of the Electrician's Mate rating. The NRCC provides guidance in studying the RTM with learning objectives and study items that emphasize the important study material.

This RTM/NRCC was prepared by the Naval Education and Training Program Development Center, Pensacola, Florida for the Chief of Naval Education and Training

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THE UNITED STATES NAVY

GUARDIAN OF OUR COUNTRY

The United States Navy is responsible for maintaining control of the sea and is a ready force on watch at home and overseas, capable of strong action to preserve the peace or of instant offensive action to win in war.

It is upon the maintenance of this control that our country's glorious future depends; the United States Navy exists to make it so.

WE SERVE WITH HONOR

Tradition, valor, and victory are the Navy's heritage from the past. To these may be added dedication, discipline, and vigilance as the watchwords of the present and the future.

At home or on distant stations we serve with pride, confident in the respect of our country, our shipmates, and our families.

Our responsibilities sober us; our adversities strengthen us.

Service to God and Country is our special privilege. We serve with honor.

THE FUTURE OF THE NAVY

The Navy will always employ new weapons, new techniques, and greater power to protect and defend the United States on the sea, under the sea, and in the air.

Now and in the future, control of the sea gives the United States her greatest advantage for the maintenance of peace and for victory in war.

Mobility, surprise, dispersal, and offensive power are the keynotes of the new Navy. The roots of the Navy lie in a strong belief in the future, in continued dedication to our tasks, and in reflection on our heritage from the past.

Never have our opportunities and our responsibilities been greater.

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CHAPTER 1

CAREER PROGRAM

This rate training manual is designed to help you meet the occupational standards for advancement to Electrician's Mate First Class and Chief Electrician's Mate. Chapters 2 through 11 of this training manual deal with the technical subject matter of the Electrician's Mate rating. It is strongly recommended that you study this chapter carefully before beginning intensive study of the chapters that follow.

REWARDS AND RESPONSIBILITIES

Advancement brings both increased rewards and increased responsibilities. The time to start looking ahead and considering the rewards and the responsibilities of advancement is right now, while you are preparing for advancement to EM1 or EMC.

By this time, you are probably well aware of many of the advantages of advancement: higher pay, greater prestige, more interesting and challenging work, and the satisfaction of getting ahead in your chosen career. Also, you have probably discovered that one of the most enduring rewards of advancement is the personal satisfaction you find in developing your skills and increasing your knowledge.

The Navy also benefits by your advancement. Highly trained personnel are essential to the functioning of the Navy. With each advancement, you increase your value to the Navy in two ways. First, you become more valuable as a technical specialist in your own rating, and second, you become more valuable as a person who can supervise, lead, and train others and thus make far-reaching and long-lasting contributions to the Navy.

In large measure, the extent of your contribution to the Navy depends on your willingness and ability to accept increasing responsibilities as you advance. When you assumed the duties of EM3, you began to accept a certain amount of responsibility for the work of others. With each advancement, you accept an increasing responsibility in military matters and in matters relating to the occupational requirements of the Electrician's Mate rating.

You will find that your responsibilities for military leadership are about the same as those of petty officers in other ratings, since every petty officer is a military person as well as a technical specialist. Your responsibilities for technical leadership are special to your rating and are directly related to the nature of your work. Operating and maintaining the ship's distribution system is a job of vital importance, and it is a teamwork job; it requires a special kind of leadership ability that can be developed only by personnel who have a high degree of technical competence and a deep sense of personal responsibility.

Certain practical details that relate to your responsibilities for divisional administration supervision are discussed in chapter 10 of this training manual. At this point, let's consider some of the broader aspects of your increasing responsibilities for military and technical leadership.

YOUR RESPONSIBILITIES WILL EXTEND BOTH UPWARD AND DOWNWARD. Both officers and enlisted personnel will expect you to translate the general orders given by officers into detailed practical on-the-job language that can be understood and followed by even relatively inexperienced personnel. In dealing with your juniors, it is up to you to see that they perform their work properly. At the same time, you must be able to explain to officers any important needs or problems of the enlisted men.

YOU WILL HAVE REGULAR AND CONTINUING RESPONSIBILITIES FOR TRAINING. Even if you are lucky enough to have a highly skilled and well-trained E division, you will still find that training is necessary. For example, you will always be responsible for training lower rated men for advancement in rating. Also, some of your best workers may be transferred, and inexperienced or poorly trained personnel may be assigned to you. Or, a particular job may call for skills that none of your personnel have. These and similar problems require you to be a training specialist who can conduct formal and informal training programs to qualify personnel for advancement and who can train individuals and groups in the effective execution of assigned tasks.

YOU WILL HAVE INCREASING RESPONSIBILITIES FOR WORKING WITH OTHERS. As you advance to EM1 and then to EMC, you will find that many of your plans and decisions affect a large number of people, some of whom are not Electrician's Mates, and some of whom are not even in the engineering department. It becomes increasingly important, therefore, to understand the duties and responsibilities of personnel in other ratings. Every petty officer in the Navy is a technical specialist in his own field. Learn as much as you can about the work of other ratings, and plan your work so that it will fit in with the overall mission of the organization.

AS YOUR RESPONSIBILITIES INCREASE, YOUR ABILITY TO COMMUNICATE CLEARLY AND EFFECTIVELY MUST ALSO INCREASE. The basic requirement for effective communication is a knowledge of your own language. Use correct language in speaking and in writing. Remember, the basic purpose of all communication is understanding. To lead, to supervise, and to train others, you must be able to speak and write in such a way that others can understand exactly what you mean.

A second requirement for effective communication in the Navy is a sound knowledge of the Navy way of saying things. Some Navy terms have been standardized to ensure effective communication. When a situation calls for the use of standard Navy terminology, use it.

Still another requirement of effective communication is precision in the use of technical terms. A command of the technical language of the Electrician's Mate will enable you to receive and convey information accurately and to exchange ideas with others. A person who does not understand the precise meaning of terms used in connection with the work of his rating is at a disadvantage when he tries to read official publications relating to his work. He is also at a great disadvantage when he takes the written examinations for advancement. Although it is always important for you to use technical terms correctly, it is particularly important when you are dealing with men of lower rate. Sloppiness in the use of technical terms is likely to be very confusing to an inexperienced man.

YOU WILL HAVE INCREASED RESPONSIBILITIES FOR KEEPING UP WITH NEW DEVELOPMENTS. Practically everything in the Navy—policies, procedures, equipment, publications, systems—is subject to change and development. As an EM1 and even more as an EMC, you must keep yourself informed about all changes and new developments that might affect your rating or your work.

Some changes will be called directly to your attention, but you have to look for others. Try to develop a special kind of alertness for new information. Keep up-to-date on all available sources of technical information. And, above all, keep an open mind on the new types of control devices being developed for and incorporated within existing and new electrical systems. If you look back over the history of electrical systems since the end of World War II, you will find that a number of important changes have occurred during this time. By far, one of the most important developments was the Zener diode along with other semiconductor devices, such as the junction diode and the silicon controlled rectifier. Although these semiconductor devices are used in many of the systems with which you are familiar, magnetic amplifiers also had a place in the development of better electrical systems. These changes were necessary to cope with the ever increasing demands put upon the electrical plant. As more and more technological advances were made to systems that utilized electric power, so it was with the systems that provided the power. As a result of these ever-occurring changes, the need for increasing your technical knowledge is apparent and you must do your part to keep abreast of these changes.

THE EM BILLET

The EM is one of the general ratings. Electrician's Mates are included in the personnel allowance for practically all types of Navy ships including repair ships and tenders.

As an EM1, you may be assigned to almost any type of ship and may be required to fill the senior Electrician's Mate billet on ships the size of a destroyer and smaller. Chief Electrician's Mates are usually assigned to ships the size of destroyers and larger.

Shore billets for Chief and First Class Electrician's Mate include recruiting duty, instructor duty at a service school, recruit training commands, Naval Reserve training centers, and the Naval Education and Training Program Development Center which is located in Pensacola, Florida.

DUTIES

Electrician's Mates stand watch on generators, switchboards, and control equipment; operate electrical equipment; maintain and repair power and lighting circuits, electrical fixtures, motors, generators, distribution switchboards, and other electrical equipment; and repair and rebuild electrical equipment in electrical shops. The specific jobs and procedures for carrying out these duties are continually changing due to the development of new and improved electrical equipment and systems.

THE NAVY ENLISTED ADVANCEMENT SYSTEM

Many of the rewards of Navy life are earned through the advancement system. The basic ideas behind the system have remained stable for many years, but specific portions may change rather rapidly. It is important that you know the system and follow changes carefully. BuPers Notices 1418 will normally keep you up to date.

The normal system of advancement may be easier to understand if it is broken into two parts:

1. Those requirements that must be met before you may be considered for advancement.
2. The factors that actually determine whether you will be advanced.

QUALIFYING FOR ADVANCEMENT

In general, to qualify (be considered) for advancement, you must first:

1. Have a certain amount of time in pay grade.
2. Demonstrate knowledge of material in your mandatory Rate Training Manuals by achieving a suitable score on your command's test, by successfully completing the appropriate NRCC's or, in some cases, by successfully completing an appropriate Navy school.
3. Demonstrate the ability to perform all the practical requirements for advancement by completing the Record of Practical Factors, NAVEDTRA 1414/1.
4. Be recommended by your commanding officer.
5. For petty officer third and second candidates only, demonstrate knowledge of military subjects by passing a locally administered Military/Leadership examination based on the naval standards for advancement (NavPers 18068 series).
6. Demonstrate knowledge of the technical aspects of your rate by passing a Navywide

advancement examination based on the occupational standards applicable to your rate (those standards listed at and below your rate level).

If you meet all the above requirements satisfactorily, you become a member of the group from which advancements will be made.

WHO WILL BE ADVANCED?

Advancement is not automatic. Meeting all the requirements makes you eligible but does not guarantee your advancement. Some of the factors that determine which persons of those qualified will actually be advanced in rate are:

1. The score made on the advancement examination.
2. The length of time in service.
3. The performance marks earned.
4. The number of vacancies being filled in a given rate.

If the number of vacancies in a given rate exceed the number of qualified personnel, then all of those qualified will be advanced. More often, the number of qualified people exceeds the number of vacancies. When this happens, the Navy uses a procedure to advance those who are BEST qualified. This procedure is based on a combination of three personnel evaluation systems:

Merit rating system (annual evaluation and CO recommendation).

Personnel testing system (advancement examination score—with some credit for passing previous advancement exams).

Longevity (seniority) system (time in rate and time in service).

Simply stated, credit is given for how much the individual has achieved in the three areas of performance, knowledge, and seniority. A composite, or final multiple score, is generated from these three factors with emphasis on performance. All of the qualified candidates from a given advancement examination population are then placed on the list, based on this composite figure, with the highest achiever first, and so on down to the last qualified person in the population. Beginning at the top of the list of candidates for E-4, E-5, and E-6, advancement authorizations are issued to the number of people needed to fill existing vacancies.

Candidates for E-7 with high final multiple are designated PASS SELBD ELIG (Pass Selection Board Eligible). Their names will be placed before the Chief Petty Officer Selection Board, a BuPers board charged with considering all eligible candidates for advancement to CPO. Advancement authorizations for those being advanced to CPO are issued by this board.

Who, then, are the individuals who are advanced? Basically, they are the ones who achieved the MOST in preparing for advancement. They were not content to just qualify. They went the extra mile in their training. Through that training and their work experience they developed greater skills, learned more, and accepted more responsibility.

While the advancement system cannot guarantee that any one person will be advanced, it does guarantee that all persons within a particular rate will compete equally for the vacancies that exist.

SCOPE OF THIS RATE TRAINING MANUAL

Before studying any book, it is a good idea to know the purpose and the scope of the book. You should know that this rate training manual will give you information of the occupational standards for advancement to EM1 and EMC and that you must satisfactorily complete the nonresident career course associated with the manual before you can advance to EM1 or EMC, whether you are in the regular Navy or in the Naval Reserve.

This rate training manual does NOT give you information on the naval requirements for advancement to PO1 or CPO. Rate training manuals that are specially prepared to give information of the naval requirements are discussed in the section of this chapter that deals with sources of information.

This rate training manual does NOT give you information that is related primarily to the occupational standards for advancement to EM3 and EM2. Such information is given in *Electrician's Mate 3 & 2*, NAVEDTRA 10546-D.

The occupational standards that were used as a guide in the preparation of this rate training manual were those set forth in the *Manual of Qualifications for Advancement* (called the *Navy Enlisted Manpower and Personnel Classifications and Occupational Standards*) NAVPERS 18068 series. Therefore, changes in the Electrician's Mate qualifications or standards may not be reflected in the information given in this training manual. Since your major purpose in studying this training manual is to meet the occupational standards for advancement to EM1 and EMC, it is important for you to obtain and study a set of the most recent Electrician's Mate standards.

This rate training manual includes information that is related to both the KNOWLEDGE FACTORS and the PRACTICAL FACTORS of the standards for advancement to EM1 and EMC. However, no training manual can take the place of actual on-the-job experience for developing skill in the practical factors. The training manual can help you understand some of the technical applications, but you should combine knowledge with practical experience to develop the required skills. Use the *Record of Practical Factors*, NAVEDTRA 1414/1, in conjunction with this training manual whenever possible.

This training manual deals almost entirely with electrical equipment installed on conventional steam-driven surface ships. Before studying this manual, study the table of contents and note the arrangement of information. Information can be organized and presented in many different ways. You will find it helpful to have an overall view of the organization of this manual before you start to study it.

SOURCES OF INFORMATION

It is very important that you have an extensive knowledge of the references to consult for detailed, authoritative, up-to-date information on all subjects related to the naval requirements and to the occupational standards of the Electrician's Mate.

Some of the publications discussed in this section are subject to change or revision from time to time—some at regular intervals, others as the need arises. When using any publication that is subject to change or revision, be sure that you have the latest edition. When using any publication that is kept current by means of changes, be sure you have a copy in which all official changes have been entered.

NAVPERS AND NAVEDTRA PUBLICATIONS

The NAVPERS and NAVEDTRA publications described below include some which are absolutely essential for anyone seeking advancement and some which, although not essential, are extremely helpful.

Manual of Navy Enlisted Manpower and Personnel Classifications and Occupational Standards (Occupational Standards Manual)

The *Manual of Navy Enlisted Manpower and Personnel Classifications and Occupational Standards* gives the minimum requirements for advancement to each pay grade within each rating. The *Occupational Standards Manual* lists the naval requirements which apply to all ratings and the occupational standards that are specific to each rating.

The *Occupational Standards Manual* is kept current by means of numbered changes. These changes are issued more frequently than most rate training manuals can be revised; therefore, the training manual cannot always reflect the latest standards for advancement. When preparing for advancement, you should always check the LATEST *Occupational Standards Manual* and the LATEST changes to be sure that you know the current requirements for advancement in your rating.

When studying the standards for advancement, remember that the standards are the MINIMUM requirements for advancement to each pay grade within each rating. If you study more than the required minimum, you will of course have a greater advantage when you take the written examination for advancement. Each standard has a designated pay grade—E-4 through E-9. You are responsible for meeting all standards specified for advancement to the paygrade to which you are seeking advancement AND all standards specified for lower pay grades. The written examinations for advancement to E-6 and above contain questions relating to the practical factors and the knowledge factors of BOTH military/leadership requirements and occupational standards. Personnel preparing for advancement to E-4 or E-5 must pass a separate military/leadership examination prior to participation in the Navy-wide occupational examination. The military/leadership examinations for the E-4 and E-5 levels are given according to a schedule prescribed by the commanding officer. Candidates are required to pass the applicable military/leadership examination only once.

The RECORD OF PRACTICAL FACTORS is a special form used to record the satisfactory completion of the practical factors, both naval and occupational, listed in the *Occupational Standards Manual*. Whenever a person demonstrates his ability to perform a practical factor, appropriate entries should be made in the DATE and INITIALS column. As an EM1 or EMC, you will often be required to check the practical factors performance of lower rated men and to report the results to your supervising officer. To facilitate record keeping, group records of practical factors are often maintained aboard ship. Entries from the group records should be transferred to each individual's Record of Practical Factors at appropriate intervals.

As changes are made periodically to the *Occupational Standards Manual*, new forms of NAVEDTRA 1414/1 are provided when necessary. Extra space is allowed on the Record of Practical Factors to enter additional practical factors as they are published in changes to the *Occupational Standards Manual*. The Record of Practical Factors also provides space for recording demonstrated proficiency in skills which are within the general scope of the rating but which are not identified as minimum standards for advancement. Keep this in mind when you are training and supervising lower rated personnel. If a man demonstrates proficiency in some skill which is not listed in the Electrician's Mate standards but which falls within the general scope of the rating, report this fact to the supervising officer so that an appropriate entry can be made.

The Record of Practical Factors should be kept in each man's service record and should be forwarded with the service record to the next duty station. Each man should also keep a copy of the record for his own use.

Bibliography for Advancement Study

The *Bibliography for Advancement Study*, NAVEDTRA 10052, is a very important publication for anyone preparing for advancement. This publication lists required and recommended rate training manuals and other reference material to be used by personnel working for advancement. NAVEDTRA 10052 is revised and issued once each year by the Naval Education and Training Program Development Center. Each revised edition is identified by a letter following the NAVEDTRA number. When using this publication, be SURE you have the most recent edition.

The required and recommended references are listed by pay grade level in NAVEDTRA 10052. It is important to remember that you are responsible for all references at lower pay grade levels, as well as those listed for the pay grade to which you are seeking advancement.

Rate training manuals that are marked with an asterisk (*) in NAVEDTRA 10052 have a MANDATORY nonresident career course at the indicated pay grade levels. Credit for mandatory training courses may be obtained by passing the appropriate nonresident career course based on the mandatory training manual (additional credit will not be given if you have previously completed any EM 1 & C course), passing locally prepared tests based on the information given in the mandatory training manual, or in some cases, successfully completing an appropriate Navy school.

It is important to notice that all references, whether mandatory or recommended, listed in

NAVEDTRA 10052 may be used as source material for the written examinations, at the appropriate pay grade levels.

Rate Training Manuals

Rate training manuals are written to help personnel prepare for advancement. Some courses are general in nature and are intended for use by more than one rating; others (such as this one) are specific to the particular rating.

Rate training manuals are revised from time to time to bring them up-to-date. The revision of a rate training manual is identified by a letter following the NAVEDTRA number. You can tell whether a rate training manual is the latest edition by checking the NAVEDTRA number and the letter following the number in the most recent edition of the *List of Training Manuals and Correspondence Courses*, NAVEDTRA 10061.

There are three rate training manuals that are specially prepared to present information on the naval requirements for advancement. These manuals are *Basic Military Requirements*, NAVEDTRA 10054; *Military Requirements for Petty Officers 3 & 2*, NAVEDTRA 10056; and *Military Requirements for Petty Officers 1 & C*, NAVEDTRA 10057.

Each of these rate training manuals has a mandatory nonresident career course associated with it at the indicated pay grade levels. In addition to giving information on the naval requirements, these three books give a good deal of useful information on the enlisted rating structure; how to prepare for advancement; how to supervise, train, and lead other men; and how to meet your increasing responsibilities as you advance in rating.

Some of the rate training manuals that may be useful to you when you are preparing to meet the occupational standards for advancement to EM1 and EMC are discussed briefly in the following paragraphs. For a complete listing of training manuals, consult the *List of Training Manuals and Correspondence Courses*.

Tools and Their Uses, NAVEDTRA 10086-B is not specifically required for advancement as an Electrician's Mate. However it contains a good deal of useful information on the care and use of all types of handtools and portable power tools commonly used in the Navy.

Blueprint Reading and Sketching, NAVEDTRA 10077-D contains information that may be of value to you as you prepare for advancement to EM1 and EMC.

Mathematics, Vol. 1, NAVEDTRA 10069-C, and *Mathematics, Vol. 2*, NAVEDTRA 10071-B are two training manuals that may be helpful if you need to brush up on your mathematics. Volume 1, in particular, contains basic information that is needed for using formulas and for making simple computations. The information contained in volume 2 is more advanced than you will need for most purposes, but you may occasionally find it helpful.

Satisfactory completion of the nonresident career course associated with *Electrician's Mate 3 & 2*, NAVEDTRA 10546-D is required for advancement to EM3 and EM2. If you have met this requirement by satisfactorily completing an earlier *Electrician's Mate 3 & 2* nonresident career course, you should at least glance through the latest revision of the training manual. Much of the information given in this edition of *Electrician's Mate 1 & C* is based on the assumption that you are familiar with the contents of *Electrician's Mate 3 & 2*.

Rate training manuals prepared for other ratings are often a useful source of information. Reference to these manuals will increase your knowledge of the duties and skills of other men in the engineering department. The rate training manual prepared for IC Electricians will probably be of particular interest to you.

Officer Texts

Officer texts that you may find helpful as you prepare for advancement to EM1 and EMC include *Engineering Administration*, NAVEDTRA 10858-E; and *Shipboard Electrical Systems*, NAVEDTRA 10864-C.

Nonresident Career Courses

Most rate training manuals and officer texts are used as the basis for nonresident career courses. You will find it helpful to take nonresident career courses other than those that are mandatory. For example, the completion of the nonresident career course based on *Introduction to Electronics* is strongly recommended for personnel preparing for advancement to EMC. Taking a nonresident career course helps you to master the information given in the training manual and also gives you a pretty good idea of how much you have learned from studying the book.

NAVSEA PUBLICATIONS

A number of publications issued by NAVSEA will be of interest to you. While you do not need to know everything that is given in the publications mentioned here, you should have a general idea of where to find information in NAVSEA publications.

NAVSHIPS Technical Manual

The *NAVSHIPS Technical Manual* is the basic doctrine publication of the Naval Sea Systems Command. The manual is kept up to date by means of issuing chapter changes annually or less frequently as necessary. When intra-year changes are necessary, either a new chapter is issued or a NAVSEA Notice is distributed as a temporary chapter supplement. All copies of the manual should have all changes made in them as soon as possible after the changes are received.

The following chapters of the *NAVSHIPS Technical Manual* are of particular importance to you.

Chapter Number	Title
9003	Allowances, Surveys, and Requests for Material
9004	Inspections, Records, Reports, and Tests
9400	Tables of Technical Data
9450	Lubricating Oils, Greases, and Hydraulic Fluids and Lubrication Systems
9600	Electric Plant-General
9610	Electric Power Generators and Conversion Equipment
9621	Electric Power Distribution System
9622	Storage Batteries (Portable) and Dry Batteries
9630	Electric Motors and Controllers
9640	Lighting
9660	Searchlights
9813	Mine Protection; Shipboard Degaussing Installation
9850	Motion Picture Equipment
9883	Engineering Casualty Control

NAVSEA Journal

The *NAVSEA Journal* is a monthly publication which contains interesting and useful information on all aspects of shipboard engineering. The magazine is particularly useful because it supplements and clarifies information contained in the *NAVSHIPS Technical Manual* and because it presents information on new equipment, policies, and procedures.

Manufacturers' Technical Manuals

The manufacturers' technical manuals that are furnished with most electrical components and many types of equipment are valuable sources of information on operation, maintenance, and repair. The manufacturers' technical manuals for generator sets and other electrical equipment are usually given NAVSEA numbers.

TRAINING FILMS

Training films available to naval personnel are a valuable source of supplementary information on many technical subjects. Films that may be of interest are listed in the *United States Navy Film Catalog*, NAVSEA 10-1-777. Supplements to the Film Catalog carry the number NavAir 10-1-777.

When selecting a film, note its date of issue listed in the film catalog. As you know, procedures sometimes change rapidly. Thus, some films become obsolete rapidly. If a film is obsolete only in part, it may sometimes be shown effectively if before or during its showing you carefully point out to trainees the procedures that have changed. For this reason, if you are showing a film to train other personnel, take a look at it in advance if possible so that you may spot material that may have become obsolete and verify current procedures by looking them up in the appropriate sources before the formal showing.

CHAPTER 2

SAFETY

This chapter is about safety. It covers the responsibilities of the senior petty officer in the performance of evolutions where safety is necessary to accomplish assigned tasks successfully.

RESPONSIBILITY FOR SAFETY

Responsibility for the safety of personnel is vested in the commanding officer. Article 0712 of *U.S. Navy Regulations* reads as follows: "The Commanding Officer shall require that all persons concerned are instructed and drilled in applicable safety precautions and procedures; that they are complied with and that applicable safety precautions or extracts therefrom are posted in appropriate places. In any instance where safety precautions have not been issued or are incomplete, he shall issue or augment such safety precautions as he deems necessary, notifying, when appropriate, higher authorities concerned."

While the commanding officer cannot delegate his responsibility for the safety of all personnel under his jurisdiction he must necessarily delegate his authority to all officers and petty officers under his command to ensure that all prescribed safety precautions are understood and enforced according to the above article.

As the leading Electrician's Mate, your responsibilities regarding safety may be grouped into three areas as follows:

Responsibilities concerning the EM Group or E Division–these responsibilities include ensuring that all men in the group are aware of and are observing all shipboard safety precautions, especially those regarding electrical safety.

Responsibilities concerning nonelectrical ratings–as an EM1 or Chief Electrician's Mate, you will automatically be considered an expert on electrical safety precautions. Thus, you have a responsibility to educate the men, whose primary duties are nonelectrical, in these precautions. The responsibilities in this area are ever increasing as more and more electrical machines and equipment are being utilized for the various jobs aboard ship.

Responsibilities as a petty officer–in this area you have the same responsibilities as all other petty officers of equal paygrades in enforcing all safety precautions.

ELECTRIC SHOCK

The flow of current through the body is the cause of electric shock. Factors determining the extent of the body damage due to electric shock are the amount and duration of the current flow, the parts of the body involved, and the frequency of the current, if a.c. In general, the greater the current or the longer the current flows, the greater will be the body damage. Body damage is also greatest when the current flow is through or near nerve centers and vital organs. Sixty-hertz current is considered slightly more dangerous than current either of a lower frequency or d.c. This difference is small, however, and the same precautions that apply to 60-hertz a.c. also apply to direct current.

Men differ in their resistance to electric shock, and consequently, an amount of current that may cause only a painful shock to one man might be fatal to another. Table 2-1 presents the effects of 60-hertz currents flowing through the body from hand to hand or hand to foot. Summarizing the table, it can be said that at approximately 1 ma. (0.001 ampere) shock is perceptible; at approximately 10 ma. (0.010 ampere) shock is sufficient to prevent voluntary control of the muscles; and at approximately 100 ma. (0.1 ampere) shock is fatal, if it lasts for 1 second or more.

High-frequency currents of approximately 200 Hz and above have a tendency to flow along the surface of the skin (skin effect) and persons coming into contact with these currents usually suffer severe burns, although the current may not penetrate the body. In addition to the possibility of severe burns or death, involuntary movements, as a result of electrical shock, can cause other types of serious injuries resulting from falls, contact with rotating machinery or heated materials, etc.

Serious injuries of this nature can occur without the real cause receiving widespread attention. Two conditions must be present for an electric current to flow through the body and cause electric shock. First, the body or some part of the body must form part of a closed circuit, and second, somewhere in the closed circuit there must be a voltage, or a difference in potential, to cause a flow of current. It follows then, that to prevent electric shock you should ensure that your body never forms part of a closed circuit (make certain that your body is well insulated from ground).

Tests made by the National Bureau of Standards show that the resistance of the human body may be as low as 300 ohms under unfavorable conditions such as those caused by salt water and perspiration. This indicates immediately that it is possible for a potential difference as low as 30 volts to cause the fatal 0.1 ampere flow of current through the body. It is true that this is an extremely unlikely condition; however, it leaves no doubt as to the dangers involved or to precautions necessary regarding the 120-volt circuits aboard ship.

Practically all electric shocks are due to human error, rather than equipment failure. Equipment may suddenly fail and cause fatal shock even if skillfully designed for safety, thoroughly tested before use, and used in accordance with applicable safety precautions. This can happen, but rarely does. Nearly all the shipboard deaths are caused by unauthorized use of, or unauthorized modifications to, equipment; failure to observe the applicable safety precautions when using, or when working on or near energized equipment; failure to repair equipment which is known to be defective and has previously given a mild shock to users; failure to test and inspect equipment for defects; or failure to remedy all defects found by tests and inspections. All of these failures may be summarized as failure to observe applicable safety precautions.

Table 2-1.—60 Hertz Current Values Affecting Human Beings

Current Value	Effects
Less than 1 ma.	No sensation.
1 to 20 ma.	Mild sensation to painful shock, may lose control of adjacent muscles between 10 to 20 ma.
20 to 50 ma.	Painful shock, severe muscular contractions, breathing difficult.
50 to 100 ma.	Same as above, only more severe, up to 100 ma.
100 to 200 ma.	A heart condition known as ventricular fibrillation may occur anywhere between 100 and 200 ma. causing death almost immediately.
Over 200 ma.	Severe burns and muscular contractions so severe that the chest muscles clamp the heart and stop it for the duration of the shock.

ELECTRICAL SAFETY PRECAUTIONS

Preventing injury or death from electric shock and damage to electrical equipment requires strict adherence to applicable electrical safety precautions by all personnel.

In addition to the general electrical safety precautions as discussed in *Electrician's Mate 3 & 2*, NavEdTra 10546-D, and *NAVSHIPS Technical Manual*, there are other special precautions that apply to specific electrical equipment and to certain types of electrical jobs. As an EM1 or Chief Electrician's Mate you must be thoroughly familiar with these precautions as applied to the equipment and electrical work on your ship. It is your responsibility to stop work until safety violations are corrected, whenever they occur.

WORK AREA SAFETY

In any work area, certain hazards can be found. Ground rules must be set and followed. Past problems and mistakes make it mandatory that these instructions be posted in your work areas. To alert the individual, warning and danger signs must be posted. For the worker, operating instructions and safety precautions must be posted. Also, applicable first aid instructions are posted.

Let us examine some of the safety features found in electrical work areas. The workbench is insulated on all surface areas and rubber matting is on the deck. To further protect the worker, grounding straps are installed on the bench. For handling purposes, rubber and leather gloves are stored at the workbench along with safety glasses or face shields.

A test switchboard is normally supplied to test the various items that will come into the shop. To properly utilize the test switchboard, operating instructions, safety precautions, and high voltage signs as well as instructions in artificial respiration and heart massage are posted.

On or close by any switchboard are found the same written items mentioned for test switchboards. Rubber matting is also installed and protective barriers are provided to prevent unauthorized entry to the rear of service switchboards.

The previously mentioned information is applicable to equipment installed and operated in the battery locker. However, because of the nature of the work involved, added precautions are found pertaining to the mixing and handling of the electrolyte and precautions and warnings related to high hydrogen gas mixtures.

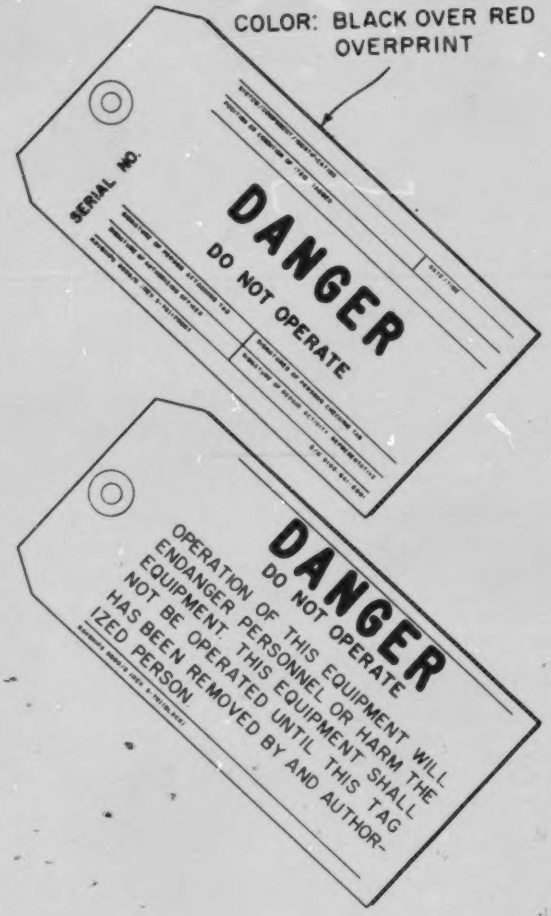
In all the work areas mentioned, the posted items and safeguards are there to instruct and protect the individual. They must remain intact and in optimum condition.

In most electric shops there are various types of rotating machinery such as bench grinders, coil winders, lathes, and drill presses. Common sense safe practices apply to all types of power-driven tools; for example, do not attempt to operate a machine with which you are not familiar. Likewise always make sure there is plenty of light anytime you are operating electrical tools.

Before operating a machine be sure the machine guards are in place (machine guards should be kept in position at all times unless removal is authorized by a supervisor or during repairs and inspections). To minimize the hazard of getting caught in the machine, don't wear loose or torn clothing, gloves, neckties, long sleeves, wrist watches, wrist bands, or neck chains.

When operating a machine do not lean against it or allow others to. Clamp work pieces securely to the machine and do not exceed the recommended depth of cut, cutting speed, or feed. Wear goggles, a face shield, or other authorized eye protective devices when you are grinding or when flying chips may be a hazard. Ensure that others in the immediate area do the same. If clothing gets caught in the machine, secure the power immediately. If you must leave the machine unattended, secure it.

During repairs or adjustments, shut off the machine, take the necessary precautions by attaching a warning tag to the switch to warn others not to energize it (fig. 2-1). Chips should be removed with a brush or other suitable tool, rather than by hand or with compressed air. The area around the machine should be kept clear of obstructions and in a nonslippery condition.


COLOR: BLACK OVER RED OVERPRINT
SERIAL NO.
DANGER
DO NOT OPERATE
DANGER
DO NOT OPERATE
OPERATION OF THIS EQUIPMENT WILL ENDANGER PERSONNEL OR HARM THE EQUIPMENT. THIS EQUIPMENT SHALL NOT BE OPERATED UNTIL THIS TAG HAS BEEN REMOVED BY AND AUTHORIZED PERSON.

40.67(67B)C

Figure 2-1.—Danger tag.

When working around energized machines take care not to distract the operator. If you are using portable electric equipment, take special care that the cord is clear of all moving machine parts.

PORTABLE METAL CASE ELECTRICAL EQUIPMENT

When an operator is using a portable metal case tool on an ungrounded distribution system, assuming all connections are correct and that the plug is inserted in the right position, the three lines of defense that protect him from electric shock are (1) the insulation on the distribution system, (2) the insulation on the tool and cord, and (3) the grounding conductor.

If the insulation resistance of the distribution system is not free of grounds and the insulation of the tool is not sound, then the only line of defense left for an operator is the grounding conductor. It is of vital importance that the ground wire connections between the metal housing of the tool and the steel structure of the ship remain intact and have a resistance value of less than 1 ohm.

To ensure that all these requirements are met, initial and periodic inspections are necessary. The frequency and types of tests and inspections necessary are found in *NAVSHIPS Technical Manual*, Chapter 9600.

It is suggested that, at the discretion of the commanding officer, a list be maintained of portable equipment which require testing on a set cycle depending on ship conditions. The list should include portable hand-held electric tools that are permanently charged out or are on loan to other shipboard departments or divisions, and electrical equipment which is frequently touched, such as hot plates, coffee makers, toasters, portable 120-volt vent sets, and movie projectors.

SOLVENTS AND VOLATILE LIQUIDS

The choice of a solvent will depend upon availability, the degree of fire risk involved, and the facilities for maintaining adequate ventilation. Gasoline or benzine should not be used for cleaning purposes under any circumstances. The following are the three principal solvents approved for use in removing oil, grease, etc. from electrical current carrying parts or insulation.

Inhibited methylchloroform (1, 1, 1 trichloroethane, as covered by the latest issue of Federal Specifications 0-T-620) should be restricted to those cleaning jobs where other cleaning agents, such as soap and water or type II dry cleaning solvent are unsatisfactory, and should be distributed in small quantities (pint cans), to avoid indiscriminate use from open buckets for cleaning jobs such as bilge cleaning, etc.

Inhibited methylchloroform may be very injurious to certain varnishes and insulation if allowed to collect in pockets where it does not evaporate readily. Before using, observe the action on a small area or sample of the insulating material. If it is apparent that it will injure the varnish or insulation, another solvent should be selected.

An inhibitor is added to methylchloroform to permit its use on aluminum. Inhibited methylchloroform itself is nonflammable and nonexplosive, but after 90 percent evaporation, the residue contains high percentages of flammable inhibitor.

Inhibited methylchloroform will cause rusting on bare ferrous surfaces if it is not completely evaporated or otherwise removed at the completion of the cleaning operation. It should not be allowed to come in contact with a commutator or brushes as unsatisfactory commutation may result.

This solvent produces a hypnotic effect when breathed for relatively short periods of time and, when used without adequate ventilation, the fumes will displace the air and may suffocate those in the area. The hypnotic effect makes the victim unresponsive to dangers as well as unresponsive to odors. Therefore, every reasonable effort must be made to ensure liberal ventilation through use of exhaust fans or portable blowers whenever personnel use this solvent for more than a few minutes. In the rare cases when such means of ventilation are impractical, an air line respirator or self-contained breathing apparatus must be used when the work is to continue for more than a few minutes. When personnel are working below decks, it is suggested that an observer be on hand out of range of the fumes to respond to the workers' safety, in case of accident. Personnel should be instructed to avoid prolonged or repeated breathing of the vapors of inhibited methylchloroform or prolonged or repeated contact with the skin by taking a 15-minute break (away from the fumes) for each one-half hour worked. Inhibited methylchloroform should not be used on hot equipment because the accelerated evaporation will increase the toxic hazard. On contact with open flame, this solvent can form phosgene, which is highly toxic.

TRICHLOROETHYLENE, as covered by the latest issue of Federal Specification 0-T-634 is a chlorinated solvent which is nonexplosive and noninflammable, but has appreciable toxic effects. Trichloroethylene is used in a vapor process to degrease metals on tenders which are outfitted for this process. It should not be used for cleaning electrical insulation because of its strong solvent action on these materials. In general, the same health and safety precautions apply as those listed above for inhibited methychloroform.

SOLVENT, DRY CLEANING, TYPE II, as covered by the latest issue of Federal Specification P-D-680, is a safety type solvent in which the fire and health hazards have been minimized. Nevertheless, precautions against fire and explosion should be observed. The efficiency of this solvent is somewhat less than that of the chlorinated solvents, and ill effects to personnel are also reduced. Experience has shown that this solution has an injurious effect on some types of insulation. Before it is used, a test should be made by applying the solution to a small spot on the insulation concerned to determine whether it is affected by the solvent.

When a solvent is being used, the two greatest hazards are fire and suffocation. To minimize the possibility of fires, any supplementary lighting required should be furnished by vaporproof or watertight portable lights. The nozzles of any sprayer or atomizer being operated should be grounded. You should be careful not to produce sparks by striking metallic objects together. No solvent should be used on hot equipment or open flames and, naturally, you should have fire extinguishers available for immediate use.

Prevention of suffocation can be most readily effected through liberal ventilation by exhaust fans or other suitable means. As mentioned before, if the cleaning must be done in a space which lacks adequate ventilation, an airline mask, self-contained breathing apparatus, or preferably, fresh air supplied from outside the enclosure through exhaust fans or portable blowers should be provided. It should be noted that when inhibited methylchloroform or trichloroethylene is used a chemical cartridge respirator will not prevent suffocation, since the vapor from these solvents displaces air and oxygen. Saturation of the user's clothing should be avoided and no less than two persons should be assigned to cleaning operations in a single compartment.

BATTERY LOCKERS

Battery lockers must be provided with adequate ventilation to remove the explosive mixture of hydrogen and air. When batteries are being charged, hydrogen is liberated; if the surrounding air contains from 4 to 8 percent hydrogen, a mixture is formed that will burn if ignited. If the mixture contains more than 8 percent hydrogen, it will explode. Hence, ample ventilation is necessary to keep the hydrogen concentration below an established safe limit of 3 percent.

When a large number of batteries is concentrated in a single compartment, the ventilation problem becomes serious, and care must be exercised to ensure that the ventilation system is operating at all times. The system should be supplied with fresh air from the exterior of the ship, and the exhaust from the battery compartment should lead overboard. Battery explosions are dangerous and can result in serious injury to personnel, as well as damage to equipment.

The ventilation system, in addition to preventing the formation of the explosive mixture, provides a means of keeping the temperature of the battery locker at 95° F. or lower.

After a sealed battery compartment has been opened, it must be thoroughly ventilated before light switches are turned on, before any other electrical connections made or broken, or before work of any kind is performed. Flames and sparks must be kept away from the vicinity because storage batteries give off a certain amount of gas at all times.

The ventilation system must be operating properly before you start a charge; you must stop a charge if ventilation is interrupted; and except in an emergency, you should not resume the charge until ventilation has been restored.

A battery should always be charged at the prescribed rates; never at a higher finishing rate than that indicated on the nameplate.

You should use only tools with insulated handles while servicing a battery, and you must take care not to short-circuit the terminals. Never make repairs to battery connections when current is flowing in the circuit, and never connect or disconnect batteries from the charging line without first turning off the charging current. When batteries are used with one terminal grounded, the grounded terminal should be disconnected first when removing the battery and connected last when you replace the battery. By this action, you will avoid the possibility of grounding the hot terminal and shorting the battery when the ungrounded terminal is disconnected first.

When mixing electrolyte, always pour the acid into the WATER. NEVER pour the water into acid. The acid must be added slowly to prevent excessive heating and cautiously, to prevent splashing. Stir the solution continually during mixing because the acid is heavier than the water and will settle to the bottom of the container. The solution becomes very hot when the concentrated acid is diluted.

Personnel who handle or mix electrolyte must wear rubber aprons, rubber boots, and rubber gloves to prevent splashing the acid on the skin or clothing. The eyes in particular must be protected by goggles.

All batteries must be kept clean and free from the accumulation of acid and dirt; otherwise, corrosion will occur and will eventually lead to troublesome grounds. Grounds are formed by the collection of dirt and acid on the tops of cells and sides of a battery. They cause a dissipation of battery energy and disarrangement of the circuit in which the battery is connected. Also, a ground in the vicinity of a battery can furnish a spark that will ignite an explosive mixture.

You must exercise caution when using salt water around storage batteries or spilled battery acid. A chemical reaction between sulphuric acid and salt produces chlorine gas, which is fatal even in very small concentrations.

SERVICING SWITCHBOARDS

Switches should be operated with the safety of both the operator and other personnel in mind. Before closing any switch, be sure that the circuit is ready in all respects to be energized and that any men working on the circuit are notified that it is to be energized.

When operating circuit breakers or switches, use only one hand if possible. Use good judgment in replacing blown fuses. Only fuses of 10 ampere capacity or less should be removed or replaced in energized circuits. Fuses larger than 10 ampere ratings should be removed or replaced only when the circuit is deenergized. Work should not be done on any energized circuit, switchboard, or other piece of electrical equipment unless absolutely necessary. Deenergize any circuits or equipment to be worked on by opening all switches through which power can be supplied and then test the circuit with a voltmeter or voltage tester. You should then tag these switches with warning tags. In case more than one party is engaged in repair work on a circuit, a warning tag for each party should be placed on the supply switches.

When checking to see whether circuits are deenergized before starting repair work on switchboards, be sure to check metering and control circuits as some instrument transformers will be energized even though main circuit breakers are open.

When military considerations require electrical repair work on energized switchboards, permission to do the work should be obtained from the commanding officer. The work should be done only by adequately supervised personnel who are fully aware of the dangers involved.

Ample illumination should be provided and men should be stationed by circuit breakers or switches (and a telephone, if necessary) so that the circuit or switchboard can be deenergized immediately in case of an emergency. A man qualified in first aid for electric shock should also be immediately available.

To minimize the chances of an emergency during work on energized circuits or equipment where the voltage exceeds 30 volts, the person doing the work should not wear a wrist watch, rings, watch chain, metal articles, or loose clothing which might make accidental contact with live parts or which might accidentally catch and throw some part of his body in contact with live parts. The clothing and shoes he is wearing should be as dry as possible.

The worker should be insulated from ground. Suitable insulating materials are rubber mats, dry phenolic material, dry wood, dry canvas, or even several thicknesses of heavy dry paper. Be sure that the material used is dry, free of holes, and that no conducting material is embedded in it. Cover sufficient area so that enough latitude is permitted for moving around during work.

When practicable, the worker should also be insulated from any live metal parts near the area in which he is working.

While working, personnel should wear rubber gloves on both hands if the type of work permits it; otherwise they should wear a rubber glove on the hand not handling the insulated tools. As far as practicable, a worker should use only one hand in accomplishing the work.

REMOVING METERS AND INSTRUMENT TRANSFORMERS

When removing or installing switchboard and control panel meters and instrument transformers you should exercise care to avoid electric shock to yourself and damage to the transformers and meters. Keep in mind that some potential transformer primaries may be energized even though all power circuit breakers are off. In most installations potential transformer primaries are fused, and the transformer and associated meter can be removed after pulling the fuses for the transformer concerned. You must exercise care, however, in disconnecting the transformer and meter leads to avoid contact with nearby energized leads and terminals.

CONNECTING AND DISCONNECTING SHORE POWER

The primary hazard involved in connecting and disconnecting shore power is the possibility of personnel coming in contact with energized conductors. Another hazard to consider is the condition of the shore power cable and its associated terminal box (both are vulnerable to exposure from sea spray, which is a primary cause of grounds and short circuits). Reverse rotation of electrical rotating equipment can also cause numerous problems with the possibility that some equipment will burn out.

Because of the hazards involved, connecting and disconnecting shore power should be supervised by the senior EM and the electrical officer. The procedures for connecting and disconnecting shore power and precautions to be observed will vary slightly depending on the type of ship concerned.

The procedure applicable to most ships is, to shut off and tag the shore power circuit breaker; to test the terminals in the ship's shore power terminal box with a voltage tester to ensure that they are deenergized; and to test the insulation resistance between terminals and ground with a megger before connecting the shore power cable. (The fuses for shore power voltmeter and/or indicating light transformer primaries must be pulled to get an accurate insulation resistance reading between the shore power terminals.)

When connecting the shore power cable, connect one end to the terminals in the ship's shore power terminal box according to the phase or polarity markings in the box on the cable, check the terminals in the source shore power terminal box to ensure that they are deenergized, and then connect the other end of the shore power cable to these terminals observing polarity or phase markings as before.

At the ship's shore power terminal box, connect the phase sequence meter (if three phase a.c.) to the proper terminals, then energize the cable from the shore power source. Check for proper phase sequence by observing the phase sequence meter. If the phase sequence is correct, deenergize the cable, disconnect the phase sequence meter, and reenergize the cable.

If the phase sequence is incorrect, deenergize the cable, recheck the phase sequence meter connections and, if they are correct, interchange any two of the shore power cable conductors. Then, energize the cable from the shore power source again, ensure that the phase sequence is correct, deenergize the cable, disconnect the phase sequence meter, and reenergize the cable.

The above procedure is modified slightly for ships supplied entirely with d.c. power as the shore power polarity should be checked with a polarity indicating voltage tester. This is to prevent reverse polarity and to prevent incorrect connection of the neutral wire, which would result in having high voltages on low voltage circuits.

The procedure also differs slightly for the plug-in type of shore power cable presently being installed on new ships. New ships are provided with switchboard-mounted, phase-sequence indicators for monitoring the phase sequence of the connected shore power before the ship's shore power circuit breaker is closed. Then, meters are permanently connected and are located on the control benchboard, if one is provided, or on the switchboard bus tie unit containing the shore power circuit breaker.

Periodic checks should be made to ensure that the cable remains intact and is not subject to being pinched, stretched, in contact with a shore steam line, or to any other condition that may cause damage to the cable.

Other pier services can be found in the vicinity where the shore power cable is located. One, previously mentioned, is the shore steam line, a hazard to both personnel and cable insulation. A person can be badly burned if he comes in contact with such a line, and if the line should rupture, the shore power cable should be deenergized. Shore telephone connection boxes have potentials in excess of 35 volts and must be treated as such. The shore water line is a lesser problem, but it could release water under pressure near electrical connection boxes.

To disconnect the shore power cable after the electrical load has been shifted to the ship's generators, ensure that the ship's shore power circuit breaker is off and tagged and that the supply circuit breaker at the shore power source is off and tagged. At the source shore power terminal box, test the terminals to ensure that they are deenergized and disconnect the cable. At the ship's shore power terminal box, test the terminals to ensure that they are deenergized and disconnect the cable. If the cable is the plug-in type, unplug the cable, then test the male prongs of the plug to ensure that the cable is deenergized before you disconnect the cable.

SUPERVISING

Connecting and disconnecting shore power requires close on-the-job supervision. In some cases, the connecting and disconnecting at the shore power source will be done by personnel attached to the activity furnishing the shore power. This means that both ends of the shore power cable may be in the process of being connected or disconnected simultaneously by separate groups under separate supervisors. This requires the special attention of both supervisors in coordinating the work of the two groups.

As the supervisor attached to the ship receiving shore power, you are responsible for ensuring that the prescribed procedures for your particular ship are carried out. You are responsible for informing (in person) the supervisor attached to the activity furnishing shore power, when to energize or deenergize the shore power cable. You should also inform him, if possible, before you open your shore power circuit breaker while receiving shore power.

As the supervisor attached to the activity furnishing shore power, you are responsible for ensuring that the prescribed procedures for your activity are carried out. You are also responsible for ensuring that the shore power cable is energized only upon direct word from the supervisor or other appropriate authority attached to the ship receiving shore power. You should also inform the supervisor of the ship receiving shore power, if possible, before you open the shore power supply circuit breaker while supplying shore power.

WORK ALOFT

When radio or radar antennas are energized by transmitters, workmen must not go aloft unless advance tests show positively that no danger exists. A casualty can occur from even a small spark drawn from a charged piece of metal or rigging. Although the spark itself may be harmless, the "surprise" may cause the man to let go his grasp involuntarily. There is also shock hazard if nearby antennas are energized, such as those on stations ashore or aboard a ship moored alongside or across a pier.

An added danger exists for men working aloft. The radar or other rotating antennas may knock the men from their perch and cause them to fall. Motor safety switches controlling the motion of radar antennas must be tagged and locked open before anyone is allowed aloft near such antennas.

Men working near a stack must wear the recommended oxygen breathing apparatus. Among other toxic substances, stack gas contains carbon monoxide. Carbon monoxide is too unstable to build up to a high concentration in the open, but prolonged exposure to even small quantities is dangerous.

Each time a man goes aloft to work, he must make it a practice to:

1. Get permission of the communications watch officer (CWO) and the OOD.
2. Check with the engineer officer to ensure that the boiler safety valves are not being set.
3. Get the assistance of another man along with a ship's Boatswain's Mate who is qualified in rigging.
4. Wear a Rose safety harness. To be of any benefit, the harness must be fastened securely as soon as the place of work is reached. Some men have complained on occasion that a parachute harness is clumsy and interferes with movement. True as this may be, it is also true that a fall from the height of an antenna is usually fatal.
5. Keep both hands free for climbing. Tools are not to be carried in hand; an assistant can lift them to the work site.
6. Secure tools with preventer lines to keep them from dropping on a shipmate.
7. Keep a good footing and firm grasp at all times. The nautical expression HOLD FAST serves as a good memory device, in case one is needed.

WARNING SIGNS, PLATES, AND TAGS

Warning signs and suitable guards shall be provided to prevent personnel from coming into accidental contact with dangerous voltages, to warn personnel of possible presence of explosive vapors, to warn personnel working aloft of poisonous effects of stack gases, and to warn of other dangers which may cause injuries to personnel. Equipment installation should not be considered complete until appropriate warning signs have been posted in full view of operating personnel.

Certain types of standard electronics warning signs are available for procurement from the Commander, Philadelphia Naval Shipyard. A list of signs that are available has been distributed to all ships, commands, and shore activities. Any warning signs not listed should be ordered on a separate requesting document.

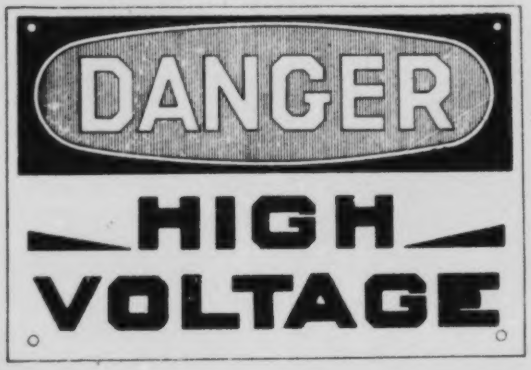
Drawings of the standard warning signs most frequently used have been prepared by the Naval Sea Systems Command.

High Voltage Warning Sign (NavSea(Ship) Drawing No. RE 10 B 608B). This sign (fig. 2-2) must be displayed at all locations where danger to personnel exists, either through direct contact with high voltage or through high voltage arc-over. Appropriate guards should also be installed at these locations.

Warning Sign for Personnel Working Aloft in Way of Smoke Pipe Gases (NavSea(Ship) Drawing No. RE 10 AA 529A). This sign (fig. 2-3) is to be displayed at the bottom and top of access ladders to electronic equipment in the way of smoke pipe gases.

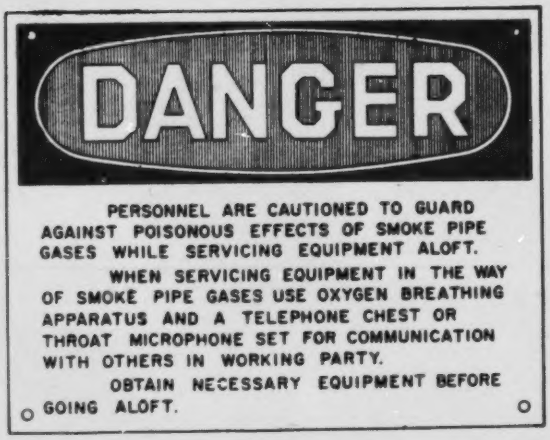
RF Radiation Hazard Warning Sign (NavSea (Ship) Drawing No. RE 10 D 2282). Four types of this sign are included in the same drawing (fig. 2-4A through D).

1. Type A. To be located on radar antenna pedestals.


DANGER
HIGH
VOLTAGE

40.67(31)

Figure 2-2.--High voltage warning sign.


DANGER
PERSONNEL ARE CAUTIONED TO GUARD AGAINST POISONOUS EFFECTS OF SMOKE PIPE GASES WHILE SERVICING EQUIPMENT ALOFT.
WHEN SERVICING EQUIPMENT IN THE WAY OF SMOKE PIPE GASES USE OXYGEN BREATHING APPARATUS AND A TELEPHONE CHEST OR THROAT MICROPHONE SET FOR COMMUNICATION WITH OTHERS IN WORKING PARTY.
OBTAIN NECESSARY EQUIPMENT BEFORE GOING ALOFT.

40.67(26D)

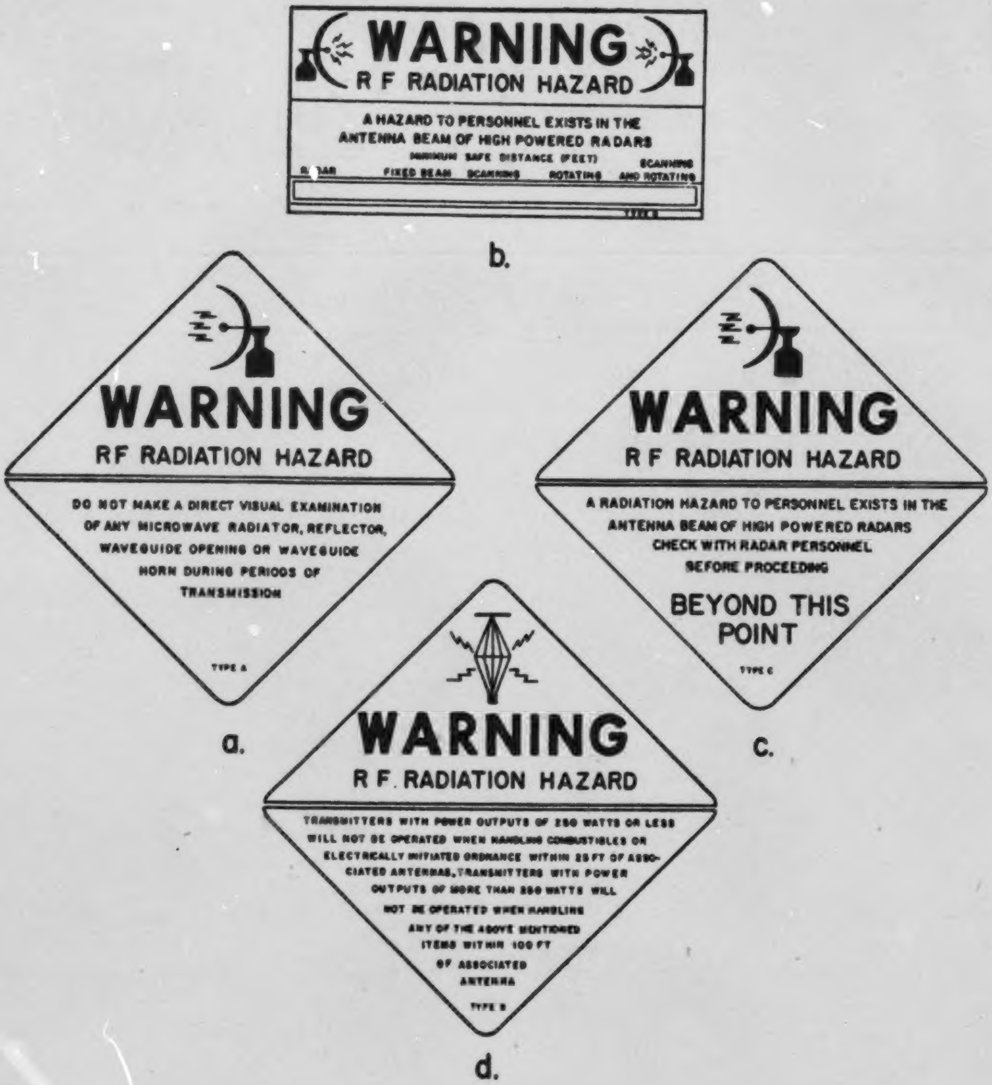
Figure 2-3.–Smoke pipe gases warning sign.

2. Type B. To be located on or adjacent to radar set controls.
3. Type C. To be located at eye level at the foot of ladders or other accesses to all towers, masts, and superstructures which are subjected to hazardous levels of radiation.
4. Type D. To be located in radio transmitter rooms in suitable locations in full view of personnel operating transmitters.

Warning Plate for Electronic Equipment Installed in Small Craft (NavSea(Ship) Drawing No. RE 10 A 589). This sign (fig. 2-5) is a warning against the energizing of electronic equipment until ventilation blowers have been operating a minimum of 5 minutes to expel explosive vapors. Although the drawing title indicates this warning plate is to be installed in small craft, it should also be displayed in all spaces where there is electronic equipment and a possibility of the accumulation of explosive vapors.

TEST EQUIPMENT

Some of the danger to personnel using test equipment are: coming into contact with live

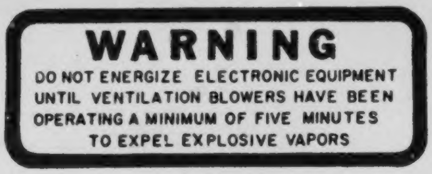

WARNING
R F RADIATION HAZARD
A HAZARD TO PERSONNEL EXISTS IN THE ANTENNA BEAM OF HIGH POWERED RADARS
MINIMUM SAFE DISTANCE (FEET)
RADAR
FIXED BEAM
SCANNING
ROTATING
SCANNING AND ROTATING
TYPE B
b.
WARNING
RF RADIATION HAZARD
DO NOT MAKE A DIRECT VISUAL EXAMINATION OF ANY MICROWAVE RADIATOR, REFLECTOR, WAVEGUIDE OPENING OR WAVEGUIDE HORN DURING PERIODS OF TRANSMISSION
TYPE A
a.
WARNING
R F RADIATION HAZARD
A RADIATION HAZARD TO PERSONNEL EXISTS IN THE ANTENNA BEAM OF HIGH POWERED RADARS CHECK WITH RADAR PERSONNEL BEFORE PROCEEDING
BEYOND THIS POINT
TYPE C
c.
WARNING
R F. RADIATION HAZARD
TRANSMITTERS WITH POWER OUTPUTS OF 250 WATTS OR LESS WILL NOT BE OPERATED WHEN HANDLING COMBUSTIBLES OR ELECTRICALLY INITIATED ORDNANCE WITHIN 25 FT OF ASSOCIATED ANTENNAS. TRANSMITTERS WITH POWER OUTPUTS OF MORE THAN 250 WATTS WILL NOT BE OPERATED WHEN HANDLING ANY OF THE ABOVE MENTIONED ITEMS WITHIN 100 FT OF ASSOCIATED ANTENNA
TYPE D
d.

40.67(76E)

Figure 2-4.—RF radiation hazard warning signs.

terminals or test leads, becoming entangled in leads or cords, and being hit by instruments that are accidentally thrown to the deck. In addition, if two or more test instruments are being used, a potential-difference between the metal cases of the instruments may be sufficient to cause severe shock.

Wires attached to portable test equipment should extend from the back of the instruments away from the observer, if possible. If this is not possible, they should be clamped to the bench or table near the instruments. When using instruments at places where vibration is present, place the instruments on pads of folded cloth,



WARNING
DO NOT ENERGIZE ELECTRONIC EQUIPMENT
UNTIL VENTILATION BLOWERS HAVE BEEN
OPERATING A MINIMUM OF FIVE MINUTES
TO EXPEL EXPLOSIVE VAPORS

40.67(140)

Figure 2-5.–Warning plate for electronic equipment installed in small crafts.

felt, or similar material. Additional precautions are necessary when you use portable test equipment during heavy seas.

To avoid injury to personnel, keep all unauthorized personnel clear of the area where portable test equipment is being used.

Ensure that the metal case of each instrument and one side of the secondary of every external instrument transformer is grounded. If equipment must be energized for testing after removal from its normal rack or mounting, ensure that all parts normally at ground potential are securely grounded.

Make sure that test leads on voltmeters or multimeters are not pulled out of the meter while the probe end is being touched to a live electric part. Avoid testing voltages in excess of 300 volts while holding test probes in the bare hand. Instead, use rubber gloves or deenergize the equipment and attach the test leads. Then, energize the equipment and read the meter. Ensure that any high voltage capacitors in the circuit and the terminals to be tested are discharged to ground before connecting or disconnecting the test leads. When feasible, check for continuity and resistance rather than directly checking voltages.

The electrical measuring instruments included in portable test equipment are of delicate construction, therefore, certain precautions are necessary to avoid damage to the instruments and to ensure accurate readings.

Mechanical shock should be avoided because, although the moving elements in electrical measuring instruments are light in weight, the bearing pressure at pivots and jewel bearings often exceeds 10 tons per square inch because of the small area of the bearing surface. Exposure to strong magnetic fields should be avoided as strong magnetic fields may permanently impair the accuracy of an instrument by leaving permanent magnetic effects in the magnet of permanent magnet moving coil instruments, in the iron of moving iron instruments, or in the magnetic materials used to shield instruments.

Excessive flow of current should also be avoided. This includes various precautions dependent on the type of instrument. In general, make connections while the circuit is deenergized, if possible, and then check all connections to ensure that no instrument is overloaded before energizing. Make sure that meters in motor circuits can handle the motor starting current. This current may be as high as 7 or 8 times the normal running current.

Never leave an instrument connected with its pointer offscale or deflected in the wrong direction. Never attempt to measure the internal resistance of a meter movement with an ohmmeter because the movement may be damaged by the current required to operate the ohmmeter.

JURY RIGS

The practice of having unauthorized or jury-rigged electrical equipment on board is a hazard and must be dealt with as such. The only way to ensure that jury-rigged items are eliminated is for you, as a senior EM, to personally see that jury rigs are not being installed. The assignment of personnel within your division for the periodic patrolling of areas is of valuable assistance, but you should check periodically yourself.

SAFETY PRECAUTIONS

Through training and experience you have become an expert in electrical safety. You have the responsibility to impart this knowledge to your subordinates and, through them, to all hands. This is where a safety education program comes into play. There is a need for formal and informal training in electrical safety and it is up to you to set it up or improve on it. Every electrician in your division must receive adequate instructions in safety precautions. There are plenty of reference materials located in the various publications. Use standard lesson plans and maintain checkoff sheets.

Safety education for the nonelectrical ratings should include information concerning electric shock and precautions they must observe when using electrical equipment aboard ship.

Some facts to bring out and points to stress to the nonelectrical ratings concerning electric shock are that voltages as low as 30 volts can be dangerous, that the dangers from electric shock are much greater aboard ship than ashore as the ship can be considered to be a floating bathtub, and that there is very little middle ground between a slight tingle and a fatal shock.

Precautions that you should stress to nonelectrical ratings using electrical equipment include: (1) always visually inspect portable electrical equipment before using (looking for damaged plugs, frayed cords, etc.); (2) never use portable electrical equipment if it is believed to be defective (have it tested and/or repaired by authorized personnel–do not test or repair it yourself); (3) do not use any personal portable electrical equipment aboard ship, unless it has been inspected and approved; and (4) always report any shock received from electrical equipment, regardless of how slight.

PROMOTING SAFETY

Promoting safety within the EM group, E division, or the ship in general will require your becoming safety conscious to the point that you automatically consider safety in every job or operation. By safety reminders and your personal example, you pass this safety consciousness on to the other men.

Periodic safety patrols or inspections made by the junior men in the group can also be helpful in promoting safety within the group and in reducing electrical hazards such as storage of foreign articles in or near switchboards, control appliances and panels, open panels or covers missing from junction boxes, etc.

Although these safety patrols or inspections are beneficial, this does not relieve the electrical supervisor of his own responsibility to conduct safety checks throughout the ship.

In addition, occasional short group discussions concerning electrical safety are recommended. These discussions may take place at any time without prior preparation. There may be at least one man in the EM group every month who receives a slight shock. This can be the basis of the discussion. Have the man concerned relate the exact circumstances under which he received the shock. The group may then discuss the slightly different conditions that might have prevailed causing the shock to be more severe or perhaps fatal.

When practical, the showing of films concerning safety will be helpful both as a safety reminder and for safety education.

ENFORCING SAFETY

Safety precautions, as all rules, laws, or regulations, should be enforced. It is your duty to take appropriate action any time you see a junior man disregarding a safety precaution. You should require that all jobs be done according to applicable safety precautions.

Doing a job the safe way in some cases may take a little longer or be a little more inconvenient, however, there is no doubt as to the importance of doing it this way.

PERIODICALS

Many sources of safety information are distributed on a monthly or quarterly basis by various naval activities. The Naval Safety Center publishes *Fathom*, a quarterly surface ship and submarine safety review. *Fathom* presents accurate and current information on the subject of nautical accident prevention. *Safety Review*, published monthly by the Naval Material Command, contains information on the safe storage, handling, or other use of products and materials. Articles dealing with safety appear often in the *Electronics Installation and Maintenance Bulletin* and the *NavSea Journal*.

CHAPTER 3

VOLTAGE AND FREQUENCY REGULATION

Sophisticated electronics and weapons systems aboard modern Navy ships require closely regulated electrical power for proper operation. To meet the increased demand for the closely regulated power, new standards for a.c. shipboard power systems have been established, and new voltage and frequency regulating equipment has been developed. Following a brief discussion of the new standards and equipment, this chapter will discuss the various types of voltage regulators for a.c. generators in use aboard Navy ships.

TYPES I, II, AND III POWER

Mil-Std-761B (Ships) of 15 July 1965 establishes standard electrical characteristics for a.c. power systems. The three basic power supplies (types I, II, and III) are described in table 3-1. The power system characteristics shown are those existing at the load and do not represent generator output characteristics. All figures are the maximum allowable percentages or times for that type power.

The terms used in table 3-1 are defined below:

STEADY STATE TOLERANCE BAND.–The maximum average voltage variations, expressed in percentage of equipment voltage rating under steady state load conditions. This includes variations caused by load changes, environment (temperature, inclination, meter error, etc.), and drift, but does not include transient load changes.

VOLTAGE UNBALANCE BETWEEN PHASES.–The difference between the highest and lowest phase voltage, expressed in percentage of the equipment voltage rating.

MODULATION AMPLITUDE.–A periodic voltage variation (peak to valley) about the equipment voltage rating, expressed in percentage of the equipment voltage rating. This is a random disturbance such as may be caused by regulators, or by reciprocating or intermittent loads.

TRANSIENT VOLTAGE LIMITS.–The changing conditions of the voltage which goes beyond and returns to the steady state tolerance band within a specified time period (recovery time), expressed in percentage of the equipment voltage rating.

VOLTAGE RECOVERY TIME.–The time elapsed from initiation of the voltage change until the voltage recovers and remains within the steady state tolerance band.

STEADY STATE FREQUENCY BAND.–The frequency variations, expressed in percentage of system frequency rating under steady load conditions. These variations are the same type as for the steady state tolerance band variations.

TRANSIENT FREQUENCY LIMITS.–The changing condition of the frequency which goes beyond and returns to the steady state frequency band within a specified time period (recovery time), expressed in percentage of the system frequency rating.

Table 3-1.—Standard Electrical Characteristics for Shipboard A.C. Power Systems

Voltage	Type I	Type II	Type III
(a) Nominal user voltage, volts rms	440 or 115	440 or 115	440, 115 or 115/200 (see note 1)
(b) User voltage tolerances			
(1) Steady state voltage (see figures 2 through 7)			
a. Average of the three line-to-line voltages	±5%	±5%	+1/2%
b. Any one line-to-line voltage including a. above and line voltage unbalance tolerance	±7%	±7%	±1 1/6%
(2) Line voltage unbalance	3%	3%	1%
(3) Voltage modulation	2%	2%	1%
(4) Voltage transient			
a. Voltage transient limits	±16%	±16%	±5%
b. Voltage transient recovery time, seconds	2	2	0.25
(5) Voltage spike (peak value) volts	2500	2500	2500
(6) The maximum worst case departure from nominal user voltage resulting from (b) (1) and (b) (3) combined, except under transient or fault conditions.	±6%	±6%	±1%
(7) The worst case voltage excursion from nominal user voltage resulting from (b) (4) a, (b) (1) a, and (b) (3) combined except under fault conditions—see note 2	±20%	±20%	5 1/2%
Waveform			
(c) Total harmonic distortion	5%	5%	3%
(d) Maximum single harmonic	3%	3%	2%
(e) Deviation factor	5%	5%	5%
Frequency			
(f) Nominal frequency (Hertz)	60	400	400
(g) Frequency tolerances			
(1) Steady state frequency	±3%	±5%	±1/2%
(2) Frequency cyclic variation	+1/2%	1/2%	1/2%
(3) Frequency transient	±4%	±3%	±1%
(4) Frequency transient recovery time, seconds	2	2	0.25
(5) The worst case frequency excursion from nominal frequency resulting from (g) (1), (g) (2), and (g) (3) combined, except under fault conditions	5-1/2%	6-1/2%	1-1/2%
Power Continuity			
(h) Typical power interruption time, seconds	0.5 to 20	0.5 to 20	0.5 to 3

Notes:

1. When a 115/200 volt, 3 phase 4 wire, wye system is supplied from line voltage regulators, the type III characteristics apply to line-to-neutral power. Line to line power characteristics may be expected to exceed these limits under certain conditions. 115/200 volt power is only supplied for aircraft servicing and avionics ships.
2. Excursions of this magnitude will only occur infrequently.

FREQUENCY RECOVERY TIME.—The time elapsed from initiation of the frequency change until the frequency recovers and remains within the steady state frequency band.

HARMONIC CONTENT.—The ratio (expressed as a percentage) of the effective value of the voltage variations remaining after elimination of the fundamental voltage to the equipment voltage rating.

SINGLE HARMONIC.—The percentage of the effective value of the voltage variation compared to the equipment voltage rating.

DEVIATION FACTOR.—The ratio of the maximum difference between the voltage wave and the harmonic content to 1.414 times the voltage rating.

$$\text{Deviation factor \%} = \frac{\text{Max. deviation}}{\sqrt{2}\ \text{nominal voltage}}\,(100)$$

Present ship service generators and distribution systems are adequate for 60 and 400 hertz type I power. Type II power differs principally from type I in having more stringent voltage requirements. Better voltage regulation at the ship service generator will not satisfy these voltage requirements as the specified voltage is at the equipment or load and not at the generator output. Static type line voltage regulators which provide type II voltage control at the load are discussed in chapter 4.

The voltage and frequency requirements for type III power cannot be met without isolating the equipment requiring the power from the rest of the power system. Motor generator sets are normally used for this purpose.

TYPES OF VOLTAGE REGULATORS

A voltage regulator consists essentially of a control element and associated mechanical or electrical means to produce the changes in the generator field current that are necessary to maintain a predetermined constant generator terminal voltage. When used on d.c. generators, voltage regulators and their auxiliary equipment function to maintain the generator terminal voltage within specified limits and to provide for proper division of the load between generators operating in parallel. When used on a.c. generators, voltage regulators and their auxiliary equipment function to maintain the generator terminal voltage within specified limits and to provide for proper division of the reactive current between generators operating in parallel.

The types of voltage regulators used in naval vessels are (1) the indirect acting rheostatic, (2) the direct acting rheostatic, (3) the rotary amplifier, and (4) the combined static excitation and voltage regulation system.

The indirect acting rheostatic type voltage regulators were used on all a.c. ship's service generators and many emergency generators until 1943. Very few of these voltage regulators are still in service, so they will not be discussed in this manual.

One voltage regulator is provided for each generator that is to be regulated. In some ship's service installations a spare voltage-sensitive (control) element is installed on the switchboard. The switchboard is provided with a transfer switch so that the spare element can be placed in service if either of the other control elements become deranged. Spare control elements are not installed for voltage regulators used on emergency generators.

DIRECT ACTING RHEOSTAT VOLTAGE REGULATOR

The direct acting rheostat type voltage regulator consists of a control element in the form of a regulator coil which exerts a mechanical force directly on a special type of regulating resistance.

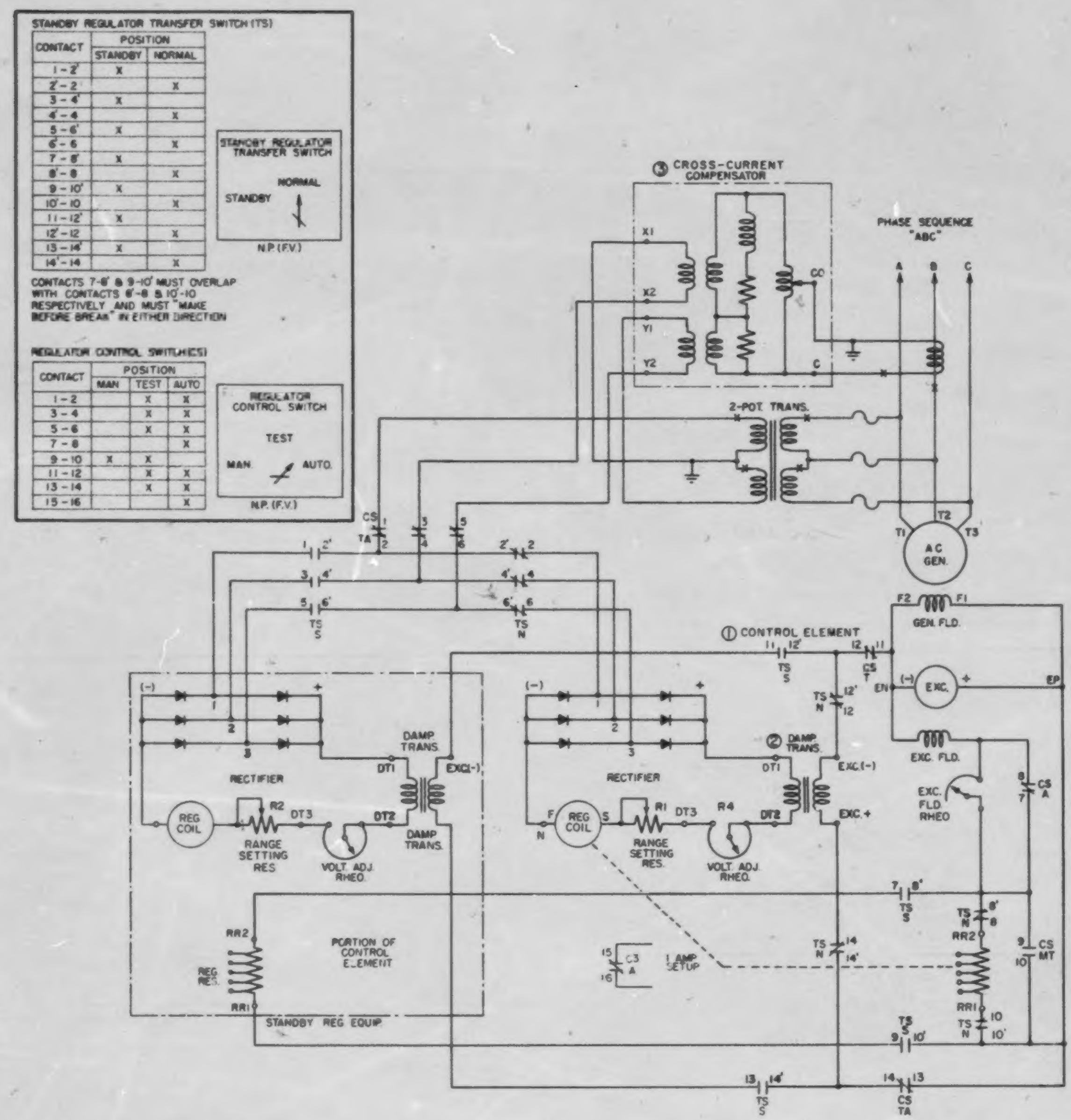
The installation of direct acting (silverstat type) voltage regulators used on emergency a.c. generators is illustrated by the schematic diagram in figure 3-1. As stated previously, in each installation one regulator controls one a.c. generator. When a standby regulator is installed, a standby regulator transfer switch is also installed to provide a switching means for substituting the standby regulator for the normal regulator.

The voltage regulator controls the voltage of the a.c. generator by the variable regulating resistance, which is built into the regulator, and is connected in series with the shunt field of the exciter. The complete regulator includes a control element ①, a damping transformer ②, and a cross-current compensator ③.

Control Element

The control element (fig. 3-2) consists of a regulator coil, which carries a spring-mounted moving arm and a regulating resistance. The regulator coil, comprises a stationary coil wound on a C-shaped iron core and a spring-mounted moving arm. The nonmagnetic spring-mounted moving arm is pivoted so that an iron armature attached to one end is centrally located in the fixed air gap of the magnetic circuit. A pusher arm and a coiled spring are attached to the other end of the moving arm. The pusher arm carries two insulated pusher pins arranged to bear against silver buttons, which are spring mounted and connected to the regulating resistance.

The silver buttons are individually mounted on leaf springs insulated from each other and connected to consecutive taps on the stationary regulating resistance plates (fig. 3-3). The resistance plates consist of tapped resistance



STANDBY REGULATOR TRANSFER SWITCH (TS)

CONTACT	POSITION	
	STANDBY	NORMAL
1 - 2'	X	
2' - 2		X
3 - 4'	X	
4' - 4		X
5 - 6'	X	
6' - 6		X
7 - 8'	X	
8' - 8		X
9 - 10'	X	
10' - 10		X
11 - 12'	X	
12' - 12		X
13 - 14'	X	
14' - 14		X

CONTACTS 7-8' & 9-10' MUST OVERLAP WITH CONTACTS 8'-8 & 10'-10 RESPECTIVELY AND MUST "MAKE BEFORE BREAK" IN EITHER DIRECTION

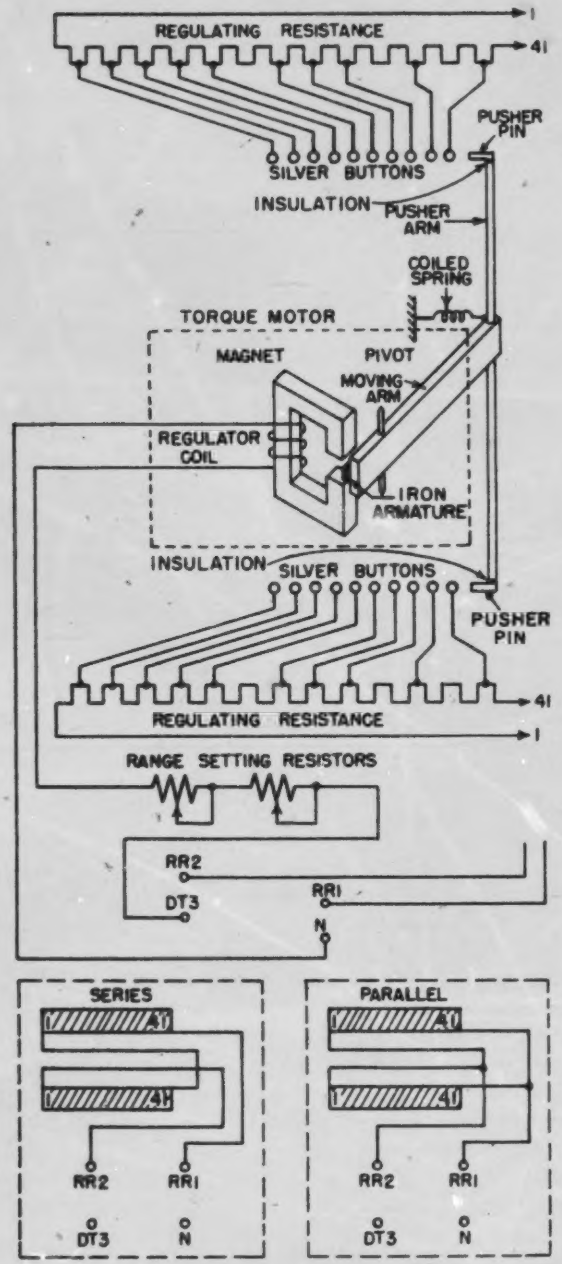
REGULATOR CONTROL SWITCH (CS)

CONTACT	POSITION		
	MAN	TEST	AUTO
1 - 2		X	X
3 - 4		X	X
5 - 6		X	X
7 - 8			X
9 - 10	X	X	
11 - 12		X	X
13 - 14		X	X
15 - 16			X

STANDBY REGULATOR TRANSFER SWITCH
NORMAL
STANDBY
N.P. (F.V.)
REGULATOR CONTROL SWITCH
TEST
MAN.
AUTO.
N.P. (F.V.)
③ CROSS-CURRENT COMPENSATOR
X1
X2
Y1
Y2
CC
C
PHASE SEQUENCE "ABC"
A
B
C
2-POT. TRANS.
T1
T2
T3
A C GEN.
F2
F1
GEN. FLD.
① CONTROL ELEMENT
(-)
EXC.
+
EN
EP
EXC. FLD.
EXC. FLD. RHEO
CS TA
CS A
CS MT
CS T
TS S
TS N
(-)
+
RECTIFIER
DAMP TRANS.
② DAMP TRANS.
DT1
DT2
DT3
EXC.(-)
EXC.+
REG COIL
F
S
N
R1
R2
R4
RANGE SETTING RES.
VOLT. ADJ. RHEO.
RR1
RR2
REG RES.
PORTION OF CONTROL ELEMENT
STANDBY REG EQUIP.
CS A
1 AMP SETUP

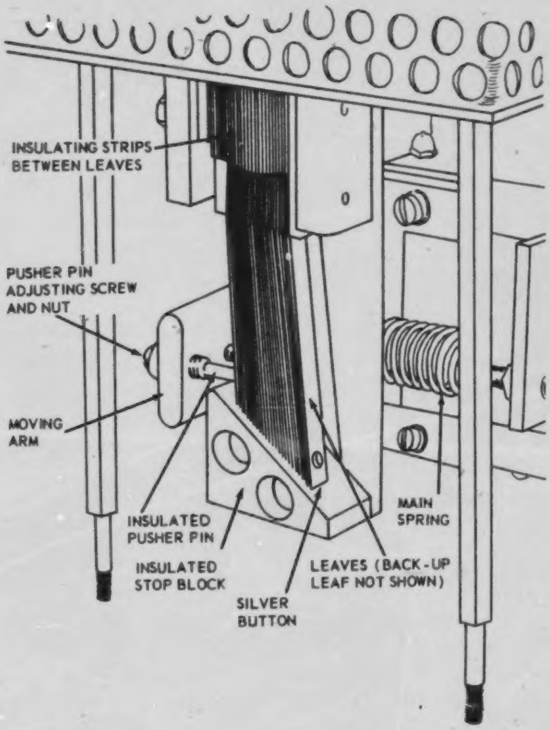
Figure 3-1.—Schematic diagram of direct acting voltage regulator installation.

27.20


REGULATING RESISTANCE
1
41
PUSHER PIN
SILVER BUTTONS
INSULATION
PUSHER ARM
COILED SPRING
TORQUE MOTOR
MAGNET
PIVOT
MOVING ARM
REGULATOR COIL
IRON ARMATURE
INSULATION
SILVER BUTTONS
PUSHER PIN
41
REGULATING RESISTANCE
1
RANGE SETTING RESISTORS
RR2
DT3
RR1
N
SERIES
41
41
RR2
RR1
DT3
N
PARALLEL
41
41
RR2
RR1
DT3
N

111.25

Figure 3-2.–Control element of direct acting voltage regulator.


INSULATING STRIPS BETWEEN LEAVES
PUSHER PIN ADJUSTING SCREW AND NUT
MOVING ARM
INSULATED PUSHER PIN
INSULATED STOP BLOCK
SILVER BUTTON
LEAVES (BACK-UP LEAF NOT SHOWN)
MAIN SPRING

111.26

Figure 3-3.–Silver button assembly.

wire embedded in vitreous enamel. The control element includes two resistance plates, one for each silver button assembly, mounted in the rear of the unit. The silver buttons connect to taps from the associated resistance plate.

The control element also includes two adjustable range-setting resistors (fig. 3-2) connected in series with the regulator coil. These resistors are used to set the range (covered by the voltage adjusting rheostat) so that rated generator voltage is obtained with the voltage adjusting rheostat in the midposition.

The primaries of two potential transformers, connected in open delta, are connected across the terminals of the a.c. generator (fig. 3-1). The secondaries of these transformers are connected to a 3-phase, full-wave rectifier through the compensator. The d.c. output of the rectifier is applied to the series circuit consisting of the regulator coil, range-setting resistance, voltage adjusting rheostat, and secondary of the damping transformer.

When the regulator coil is energized, the magnetic pull on the iron armature is balanced against the mechanical pull of the coiled spring. If the magnetic pull of the armature overcomes the pull of the spring, all of the silver buttons are separated from each other, placing maximum resistance in the field circuit. Conversely, if the tension of the coiled spring overcomes the pull of the armature, the silver buttons are pressed together, shorting out the resistance in the field circuit. Thus, the moving arm operates through its travel, depending on the direction of motion, to successively open or close the silver buttons, which increases or decreases the resistance in the exciter field. The moving arm has a short travel so that all resistance can be inserted or cut out quickly, or it can be varied gradually, depending on the required change in excitation.

For example, when the alternating voltage rises, the regulator operates because of the increasing magnetic pull on the armature. This action inserts resistance in the exciter field circuit to reduce the exciter field current and armature voltage. The primary of the damping transformer across the exciter circuit is subjected to this change in current and, through transformer action, a momentary voltage is induced in the secondary that opposes the increase in regulator coil current. This action is a form of negative feedback that lowers the magnitude of the increase in regulator coil current and thus restricts the magnitude of the decrease in exciter field current and armature voltage.

Conversely, when the alternating voltage falls, the regulator operates in the opposite direction because of the pull exerted by the coiled spring. This action shorts out resistance in the exciter field circuit, and the impulse from the damping transformer momentarily opposes the decrease in regulator coil current. This action reduces the extent of the decrease in regulator coil current and thus restricts the magnitude of the increase in exciter field current and armature voltage.

Damping Transformers

The damping transformer is an antihunt device, which consists of two windings placed on the center leg of a C-shaped laminated iron core. The primary of this transformer is connected across the output of the exciter (fig. 3-1). When a change occurs in the exciter voltage, the primary of the damping transformer induces a voltage in its secondary. The secondary voltage acts on the regulator coil to dampen the movement of the armature and thus prevents hunting and excessive changes in the generator terminal voltage.

The voltage adjusting rheostat (fig. 3-1) is used to raise or lower the regulated value of the a.c. generator voltage.

The regulator control switch has three positions (manual, test, and automatic).

When the control switch is in the MANUAL position, the a.c. generator voltage is controlled manually by the EXCITER FIELD rheostat (fig. 3-1).

When the control switch is in the TEST position (as shown), the control element is energized, but the regulating resistance is shorted out. The current in the exciter field circuit can be varied by the exciter field rheostat, and the operation of the moving arm in the control element can be observed.

When the control switch is in the AUTOMATIC position, the generator is under full control of the regulator, which will adjust the voltage to the value predetermined by the position of the voltage adjusting rheostat.

When operating the control switch from the MANUAL to the AUTOMATIC position, pause in the TEST position to allow the transient current in the regulator coil circuit to disappear without disturbing the a.c. generator voltage. The transient current is caused by the sudden connection of the damping transformer primary across the exciter armature.

Cross-Current Compensator

When two or more regulator-controlled a.c. generators operate in parallel on the same bus, it is necessary to equalize the amount of reactive current carried by each generator. This equalization of reactive current is accomplished by giving a regulator a drooping characteristic by means of a cross-current compensator provided with each a.c. generator and associated regulator.

The compensator (fig. 3-1) consists of a tapped autotransformer connected across a resistor-reactor combination. The autotransformer is energized from a current transformer connected in the B-phase of the a.c. generator between the generator terminals and the bus. Two isolation transformers, with a 1-to-1 ratio, pick up the voltage drops from the resistor-reactor combination. The output potential terminals of these transformers (X1, X2 and Y1, Y2) are connected in series with the a.c. potential leads between the secondaries of the two 440/110-volt open delta potential transformers and the 3-phase, full-wave rectifier that supplies direct current for the regulator coil. The compensator is designed to supply compensating voltages in two legs of the 3-phase regulator potential circuit to ensure that a balanced 3-phase voltage is applied to the regulator element.

The taps on the autotransformer are connected to two DIAL SWITCHES (not shown) on the compensator faceplate. One of these switches provides a coarse adjustment and the other a fine adjustment of the compensator. A total of 24 steps is available on the two switches which, in the case of the standard 12-percent compensation, gives a one-half percent change in compensation per step. The 12-percent compensation is based on 4 amperes supplied from the current transformer. If the current transformer ratio should give some other value of secondary current, the compensation settings will be affected proportionally. The compensating droop introduced by the compensator should be set to approximately 6 percent from no load to full load at 0.8 lagging power factor. However, when the proper connections and settings have been made, no further adjustments should be necessary.

Operation

When the generator circuit breaker is closed and the control switch is in the AUTOMATIC position, the generator is under control of the voltage regulator (fig. 3-1). If the a.c. generator voltage is normal, the regulator moving arm is at rest in a balanced state.

If an additional load is placed on the generator, causing the terminal voltage to drop, an increase in the exciter field current is required to increase the generated voltage and to restrict the fall in terminal voltage.

The decrease in generator terminal voltage is transmitted through the 440/110-volt potential transformers and the rectifier, thus decreasing the magnetizing effect of the regulator coil. The pull of the coiled spring overcomes the magnetic pull on the armature and moves the arm in a direction to begin closing in sequence more of the silver buttons. This action shorts out (in small steps) additional positions of the regulating resistance which, being connected in the exciter field circuit, causes the exciter field current to be increased and the a.c. generated voltage to be raised. This action prevents a further decrease in the terminal voltage. When the voltage decrease is checked, the moving arm of the regulator is again in a balanced state. The position of the regulator moving arm, however, has changed to correspond to the increase in load on the generator.

If some load is removed from the generator, causing the terminal voltage to rise, a decrease in the exciter field current is required to restore the voltage to normal. The increase in terminal voltage increases the magnetizing effect of the regulator coil so that the magnetic pull on the armature overcomes the pull of the coiled spring and moves the arm in a direction to begin separating in sequence more of the silver buttons. This action inserts (in small steps) additional portions of the regulating resistance, which causes the exciter field current to decrease and the a.c. generated voltage to lower so that the rise in terminal voltage is restricted to a small value.

The silverstat voltage regulator can increase the excitation to the ceiling voltage of the exciter, or it can reduce the excitation to the lowest value required. Because the total travel of the moving arm is only a fraction of an inch, the regulating resistance can be varied in a few cycles from maximum to practically zero, depending on the requirements of the operating conditions.

To place the voltage regulator in control for the first time, be certain that the generator line circuit breaker is open. Then, turn the regulator control switch to the MANUAL position, turn the exciter field rheostat in the direction to lower the voltage, and turn the voltage adjusting rheostat to a position midway between the lower and raise ends of its travel. Next, check to see that the brush settings are correct before bringing the a.c. generator and exciter up to speed. After bringing the generator and exciter up to speed, turn the exciter field rheostat gradually in the direction to raise the voltage and, at the same time, observe the a.c. generator voltmeter. When the voltmeter indicates the rated a.c. generator voltage, stop turning the exciter field rheostat.

To place the regulator in control of the a.c. generator voltage, turn the regulator control switch from the MANUAL to the TEST position. Pause for two or three seconds and then turn the switch to the AUTOMATIC position. Then turn the voltage adjusting rheostat until the a.c. generator reaches the rated value. After this condition has been obtained, the regulator moving arm should settle promptly after a load or voltage change. (If the arm should swing back and forth continuously, check the polarity of the damping transformer terminals. The wrong polarity or an open circuit will cause this violent swinging.) When the generator voltage is approximately at rated value, close the generator circuit breaker if the generator is operating alone.

If the generator is to be operated in parallel with a generator already connected to the bus, close the circuit breaker of the incoming generator only when the two voltages are in synchronism. The incoming generator can be connected to the line with the regulator control switch in the NORMAL or AUTOMATIC position. As soon as the two generators are operating in parallel, readjust the governor motor (speed-changer) until each unit takes its share of the kilowatt load.

To shut down the generator, remove the kW load on the generator by governor motor control rheostat while observing the wattmeter. If necessary turn the voltage adjusting rheostat in a direction to reduce the reactive load. As the load approaches zero, open the generator line circuit breaker.

Maintenance

In addition to the maintenance actions shown on the Maintenance Requirement Cards of the 3-M system and the manufacturer's detailed instructions given in the voltage regulator technical manuals, routine maintenance should include ensuring that connections are tight and strictly in accordance with installation diagrams (to maintain the effective resistance in the shunt field circuit of the exciter) and that the operation of the silver buttons is smooth throughout the entire travel of the movable core.

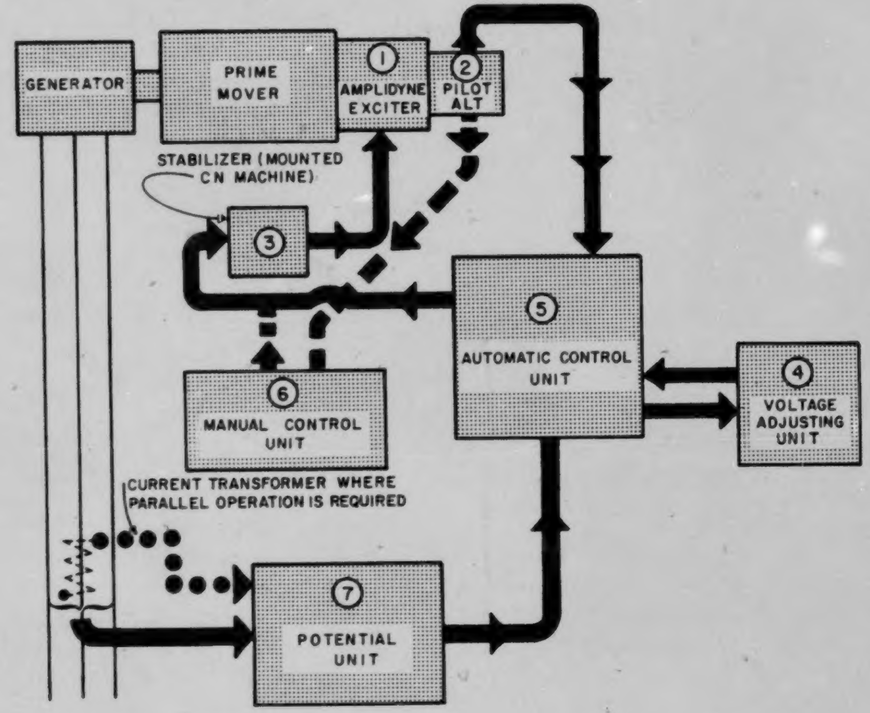
It is well to recall information about silver contacts given in the training manual, *Electrician's Mate 3 & 2*, NavEdTra 10546-D. Contacts made of silver or its alloys conduct current when discolored (blackened during arcing) with silver oxide. This discolored condition therefore requires no filing, polishing, or removing.

ROTARY AMPLIFIER VOLTAGE REGULATOR

The rotary amplifier (amplidyne) type of voltage regulator utilizes a special type of exciter that furnishes a large change in output voltage for a small change in the control field current of the exciter. The control element detects the variation of the a.c. generator voltage from a reference voltage, which can be set to a predetermined value. The variation between the actual alternating voltage and the reference voltage sends a current through the control field of the exciter to change its output voltage, and hence change the a.c. generator field current to hold the alternating voltage at the desired value.

The complete amplidyne voltage regulator equipment consists of an amplidyne exciter 1 , a pilot alternator 2 , a stabilizer 3 , a voltage adjusting unit 4 , an automatic control unit 5 , a manual control unit 6 , and a potential unit 7 ; as illustrated by the block diagram in figure 3-4. Some installations include two normal voltage regulators and one standby regulator for two a.c. generators.

A cutout switch with two positions (manual and automatic) is provided for each generator. This switch is used to connect the amplidyne exciter and the regulator for either manual or automatic control of the a.c. generator voltage.


GENERATOR
PRIME MOVER
① AMPLIDYNE EXCITER
② PILOT ALT
STABILIZER (MOUNTED ON MACHINE)
③
⑤ AUTOMATIC CONTROL UNIT
④ VOLTAGE ADJUSTING UNIT
⑥ MANUAL CONTROL UNIT
CURRENT TRANSFORMER WHERE PARALLEL OPERATION IS REQUIRED
⑦ POTENTIAL UNIT

111.27

Figure 3-4.—Block diagram of amplidyne voltage regulator system.

A transfer switch with three positions (NORMAL, GEN A, and GEN B) is provided to permit substituting the standby voltage regulator for either of the two normal regulators.

In the NORMAL position, generators A and B are connected in the normal automatic voltage control circuits of their respective regulators, and the standby regulator is disconnected.

In the GEN A position, the standby regulator has taken control from the normal regulator of generator A, and generator B is connected to its normal regulator.

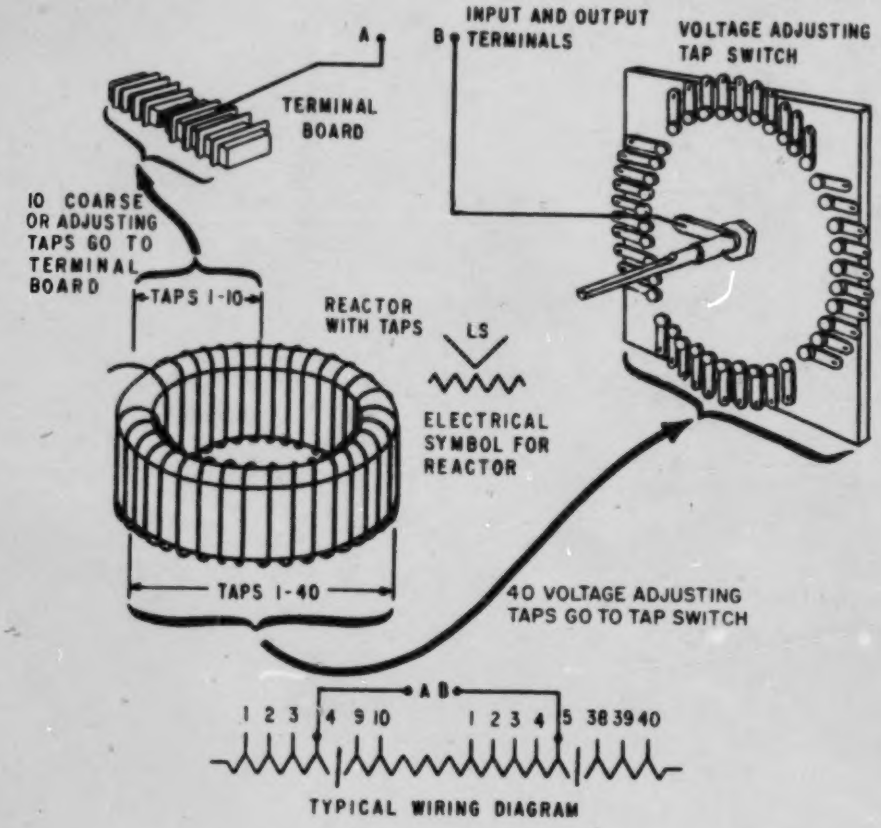
In the GEN B position, the standby regulator has taken control from the normal regulator of generator B, and generator A is connected to its normal regulator.

Amplidyne Exciter

The amplidyne exciter (fig. 3-4) is a rotary amplifier that responds quickly to small changes in control field current to cause large changes in output. It is mounted on the shaft of the prime mover and provides the excitation for the a.c. generator. The principles of the amplidyne exciter are explained in the training manual, *Basic Electricity*, NavEdTra 10086 (revised).

Voltage Adjusting Unit

The voltage adjusting unit is provided to establish the a.c. generator voltage that the regulator will maintain. This unit (fig. 3-5) consists of a tap switch and tapped saturated reactor designed for mounting directly behind the generator control panel with the handle of the tap switch on the front of the panel. The saturated reactor is the main component of the voltage adjusting unit and the heart of the regulator system.


A
B
INPUT AND OUTPUT TERMINALS
VOLTAGE ADJUSTING TAP SWITCH
TERMINAL BOARD
10 COARSE OR ADJUSTING TAPS GO TO TERMINAL BOARD
TAPS 1-10
REACTOR WITH TAPS
LS
ELECTRICAL SYMBOL FOR REACTOR
TAPS 1-40
40 VOLTAGE ADJUSTING TAPS GO TO TAP SWITCH
A B
1 2 3 4 9 10
1 2 3 4 5 38 39 40
TYPICAL WIRING DIAGRAM

111.28

Figure 3-5.—Voltage adjusting unit.

The saturated reactor determines the a.c. generator voltage, which the regulator will maintain. It consists of a tapped coil of approximately 400 turns wound on a soft iron core. The core is operated in the saturated region so that a very small change in the applied voltage and flux density will produce a large change in coil current.

Changing the taps on the coil changes the reactance of the coil circuit and the voltage level held by the regulator. Increasing the turns (to a higher tap number) increases the reactance and voltage required to maintain a given coil current. Conversely, decreasing the turns decreases the reactance and voltage required to maintain the current. Tap changing is performed only at the time of original installation or during an overhaul.

Pilot Alternator

A voltage regulator requires a "reference" or standard to which the voltage being regulated may be compared to determine whether or not the regulator should act to change the excitation of the a.c. generator. In the previously described direct acting voltage regulator this reference is provided by a coiled spring. In the amplidyne voltage regulator the reference is provided by a "boost" current of approximately 0.5 ampere from the pilot alternator. The pilot alternator (fig. 3-4) is a small permanent-magnet, single-phase a.c. generator mounted on an extension of the amplidyne shaft. The output effective voltage of the pilot alternator is essentially constant.

Potential Unit

The potential unit (fig. 3-4) provides a signal voltage to the regulator proportional to the voltage of the a.c. generator. The unit contains a potential transformer and a potentiometer rheostat and is mounted inside the generator switchboard near the current transformer and the generator circuit breaker.

The potential transformer is a special T-connected, 450-volt transformer. The potentiometer rheostat is connected in the circuit of a current transformer and is used to provide the reactive load division between generators operating in parallel.

Automatic Control Unit

The automatic control unit (fig. 3-4) contains the static elements that are required for automatic voltage control and is mounted inside the generator control switchboard. Portions of the control-unit circuit make the voltage regulator responsive to the average of the 3-phase voltages of the generator. Also, a frequency compensating network permits the regulator to hold the a.c. generator voltage practically constant with changes in the generator frequency between 57 and 63 hertz.

Stabilizer

The stabilizer (fig 3-4) is mounted on or near the amplidyne exciter and prevents sustained oscillations of the generator. It is essentially a transformer but, because it is in a d.c. circuit, the stabilizer functions only when there is a change in the exciter voltage, which is impressed across its primary. The secondary winding is connected in series with the control field of the amplidyne exciter.

When the regulator operates to change the exciter voltage, a voltage is induced in the control field circuit through the stabilizer. This momentarily affects the control field current to restrain the regulator from making excessive correction of the exciter voltage, thereby preventing hunting.

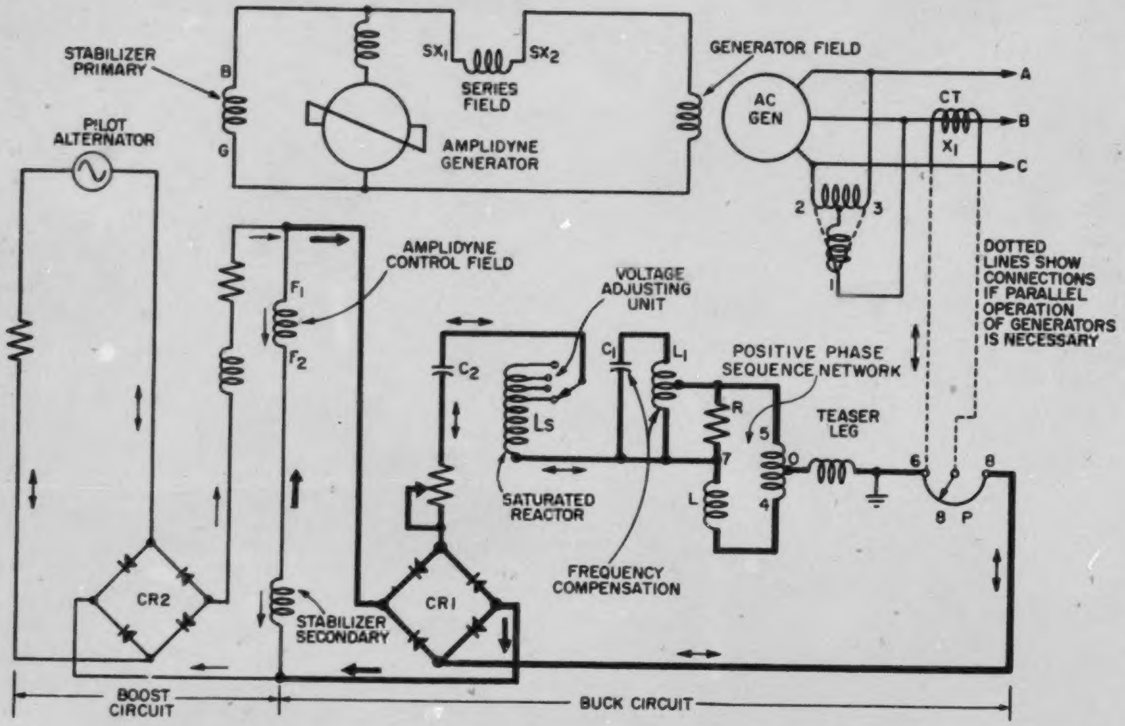
Manual Control Unit

The manual control unit (fig. 3-4) controls the voltage of the generator when the automatic control equipment is not in use and consists of two resistor plates and a single-phase full-wave rectifier. The two resistor plates are connected as a rheostat and a potentiometer, which operate concentrically. The manual control unit is mounted inside the switchboard with the operating handwheels protruding through on the front of the panel. The large handwheel provides for coarse voltage adjustment, and the small handwheel is used for fine or vernier adjustment.

Automatic Control Circuit

An elementary diagram of the automatic control circuit is illustrated in figure 3-6. The circuit consists of a buck circuit shown in heavy lines and a boost circuit shown in light lines. The a.c. portions of the circuit are indicated by double-headed arrows and the d.c. portions by single-headed arrows. The saturated reactor Ls, is energized by the a.c. generator voltage that is to be regulated and is connected to rectifier CR1. The pilot alternator feeds rectifier CR2. The amplidyne control field, F1 F2, is connected across the output of CR1 and CR2. The amplidyne-exciter supplies the a.c. generator field directly.

The voltage from the pilot alternator tries to force current through the amplidyne control field in such a direction (from F1 to F2) that the amplidyne will boost the a.c. generator voltage. The saturated reactor circuit tries to force current through the control field in the opposite direction (from F2 to F1), tending to decrease the generator voltage. When the a.c. generator voltage is near normal, the regulator is at its normal operating point and the boost current supplied by the pilot alternator is in the opposite direction and nearly equal to the buck current supplied by the saturated reactor circuit. Thus, the current through the control field is negligible, and the amplidyne excitation is


STABILIZER PRIMARY
B
G
PILOT ALTERNATOR
SX1
SX2
SERIES FIELD
AMPLIDYNE GENERATOR
GENERATOR FIELD
AC GEN
A
B
C
CT
X1
2
3
1
DOTTED LINES SHOW CONNECTIONS IF PARALLEL OPERATION OF GENERATORS IS NECESSARY
AMPLIDYNE CONTROL FIELD
F1
F2
VOLTAGE ADJUSTING UNIT
C2
C1
L1
Ls
POSITIVE PHASE SEQUENCE NETWORK
R
5
7
L
4
0
TEASER LEG
6
8
8 P
SATURATED REACTOR
FREQUENCY COMPENSATION
CR2
CR1
STABILIZER SECONDARY
BOOST CIRCUIT
BUCK CIRCUIT

27.32

Figure 3-6.—Automatic control circuit.

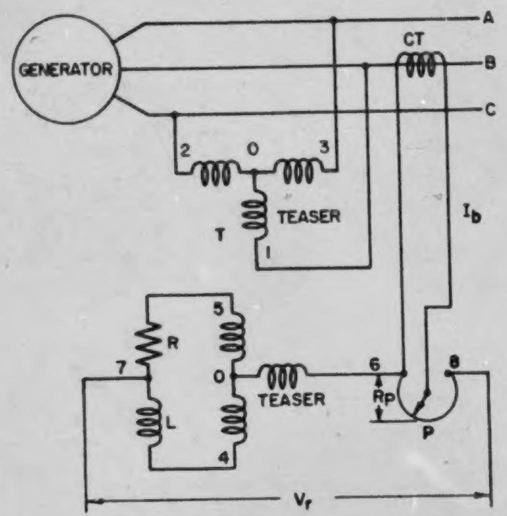
provided by the series field of the amplidyne to maintain normal terminal voltage of the a.c. generator.

However, if the generator voltage should drop slightly below normal, the buck current supplied by the saturated reactor would drop considerably. This action causes a boost current to flow in the control field, which tends to raise the a.c. generated voltage and thus prevents a further decrease in the terminal voltage. This action occurs because the pilot alternator is not affected by the generator voltage and is still trying to force a boost current through the control field.

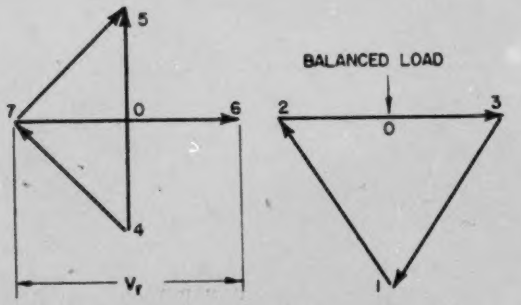
If the generator voltage should increase slightly above normal, the saturated reactor circuit would pass a large additional current through the amplidyne control field, tending to buck or decrease the a.c. generated voltage and to prevent a further increase in the terminal voltage.

Three-Phase Response Circuit

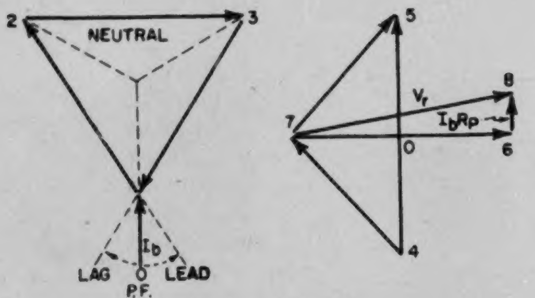
The 3-phase response circuit (fig. 3-7) consists of a T-connected potential transformer, T, a resistor, R, and an inductor, L. The resistance and inductance are in series across one secondary winding of the potential transformer (fig. 3-7A). When a balanced 3-phase voltage is impressed on the primary, 1-2-3, a voltage, 4-5-6, appears across the secondary. The voltages across the inductor, L, and the resistor, R, are 4-7 and 7-5, respectively (fig. 3-7B). The relationship of these voltages is 4-7-5, giving a resultant voltage, 7-0, in phase with and added to the voltage 0-6.



A CIRCUIT



B RESPONSE VECTORS



C REACTIVE VECTORS

27.28:33

Figure 3-7.—Three-phase response circuit.

The resulting voltage, 7-0-6 (V_r), is the voltage of the network used to energize the regulator circuits. The regulator at constant frequency will always act to maintain voltage V_r constant. If there is any deviation in generator voltage from its normal value, the system will make corrections until the 3-phase voltages, 1-2-3, are the values that will produce normal voltage V_r.

The correct phase sequence of the connections of the potential unit to the generator leads is essential to the correct functioning of this network. If the connections are reversed, for example, by interchanging the two leads from the secondary teaser winding, the voltage 7-0 would be subtracted from the voltage 0-6 instead of added to it. The voltage, V_r, impressed on the regulator would then be approximately one-fifth the required value. Thus, the regulator in attempting to go to the ceiling voltage would overexcite the generator to abnormal levels.

Frequency Compensation

The reactance of the saturated reactor (fig. 3-6) increases as the frequency increases. Thus, an increase in frequency from 60 to 63 hertz at normal 100 percent voltage would decrease the buck current, and the boost current would predominate so that the regulator would tend to hold a higher voltage. A frequency lower than 60 hertz would have the opposite effect, tending to increase the buck current so that it would predominate, and the regulator would tend to hold a lower voltage.

Therefore, a voltage regulator system utilizing a saturated reactor must be provided with a means to compensate the effect of frequency changes. Frequency compensation is provided by the addition of an inductor, L1, and a capacitor, C1, in parallel with each other and across the resistance portion of the positive phase sequence network used for 3-phase response (fig. 3-6). The values of the inductor and capacitor are such that at the normal frequency of 60 hertz they provide a resonant parallel circuit, which acts like a high resistance. The other components of the system are adjusted so that this resistance has no effect on the action of the regulator at normal frequency.

When the frequency increases above 60 hertz, the parallel circuit has a capacitive effect, which raises the apparent voltage "seen" by the saturated reactor and causes it to pass as much buck current on normal voltage at the higher frequency as at normal frequency.

When the frequency decreases below 60 hertz, the parallel circuit acts more like an inductance, which lowers the apparent voltage as "seen" by the saturated reactor and causes it to pass on more buck current at normal voltages at the lower frequency than it would at normal frequency. Thus, the parallel circuit compensates for the frequency effect on the saturated reactor, and it passes the same buck current at a particular line voltage at any frequency between 57 and 63 hertz.

Reactive Compensation

When a.c. generators are operated in parallel, the division of the load between machines is a function of the governors of the prime movers. The division of the reactive kilovoltamp is a function of the regulators, which increase or decrease the excitation of the generators.

The division of the reactive kilovoltamp between generators (when operated in parallel) is accomplished by a compensating potentiometer rheostat, R, and a current transformer, CT, provided for each machine (fig. 3-7A). The rheostat is connected in series with the Teaser leg of the T-connected potential transformer secondary. The current transformer is connected in the B phase of the generator with its secondary connected across one side of the potentiometer rheostat.

The generator voltage, 1-2-3, feeds the primary of the T-connected potential transformer (fig. 3-7A). The line current, I_b, of phase B, in which the current transformer is connected, is in phase with the line-to-neutral voltage, at unity power factor, and I_b is at 90° to the voltage, 2-3 (fig. 3-7C). At any other power factor, current I_b swings out of phase with the line-to-neutral voltage for lag or lead conditions.

The secondary voltage, 7-6 (fig. 3-7B), which is the resultant output voltage of the 3-phase response network, is in phase with the line voltage, 2-3, and is the voltage, V_r, impressed on the saturated reactor. At unity power factor, current I_b produces a voltage, 6-8, across the compensating rheostat, R, which is 90^o out-of-phase with voltage 7-6 (fig. 3-7C). The voltage 6-8 (I_bR_p) is the compensating voltage. The voltage 7-8 (V_r) is now impressed on the saturated reactor, and the regulator tends to hold the voltage proportional to 7-8.

When two duplicate generators, A and B, are operating in parallel at rated power factor, the line-currents, I, will be equal; and the voltage 7-8 (V_r) "seen" by the saturated reactors of both regulators will also be equal if the field currents are balanced (made equal), the compensating rheostats set at the same value of resistance, and the governors set for equal division of kilowatt load. Assume that a reactive load is placed on the system and that an instantaneous unbalance occurs with generator A having a weaker field and generator B having a stronger field. This unbalance can be due to slight differences in the reactances or saturation characteristics of the generators or in the characteristics of the regulators. Because the excitation is unbalanced, there is a circulating current between the two generators and their power factors are unbalanced.

The effect of this unbalance distorts the voltage triangle, 7-6-8 (fig. 3-7C), and the network voltage, 7-6, decreases slightly due to the drop in line voltage. The compensating voltage, 6-8 (I_bR_p), from the current transformer and the compensating rheostat have changed due to the unbalanced line currents and power factors. Therefore, the compensating voltage, 6-8, for generator B is greater and at a different phase angle than the corresponding voltage for generator A. Thus, the resultant voltage, 7-8 (V_r), of the two machines is unequal and different from the original voltage that the regulators were set to hold constant.

The regulators will act to change the excitation of the two generators to restore the voltage, 7-8, to equal the value, V_r, for which they are set by changing the values of the field currents so that they are balanced. The line currents and power factors will then be approximately balanced to give equal compensating voltages, 7-8, so that these voltages "seen" by the regulators for generators A and B, respectively, will be equal to each other.

The regulator holds voltage V_r constant, and the voltage, 7-6, depends on the value and phase angle of the compensating voltage, 6-8. The network voltage, 7-6, which is the difference between V_r and 6-8 and is proportional to the line voltage, has decreased slightly due to this change; thus, the line voltage will be slightly less than that maintained before the change occurred on the system. This drop in line voltage, resulting from an increase in load, is the Droop from which the individual compensation type of reactive compensation is derived.

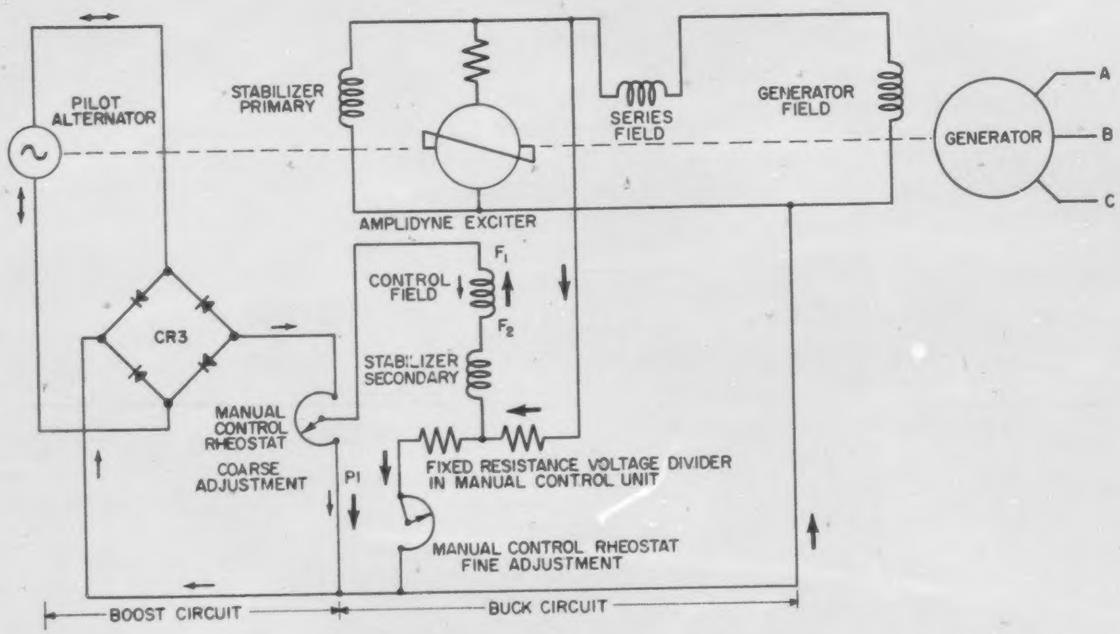
Manual Control Circuit

An elementary diagram of the manual control circuit is illustrated in figure 3-8. The buck and boost circuits are indicated by heavy and light arrows, respectively. The voltage that the amplidyne exciter will maintain across its terminals can be adjusted by the manual control rheostats. Thus, the a.c. generator terminal voltage can be varied. The manual control circuit is so designed that for any one setting of the manual control rheostat the amplidyne terminal voltage applied to the generator field will remain constant.

Operation

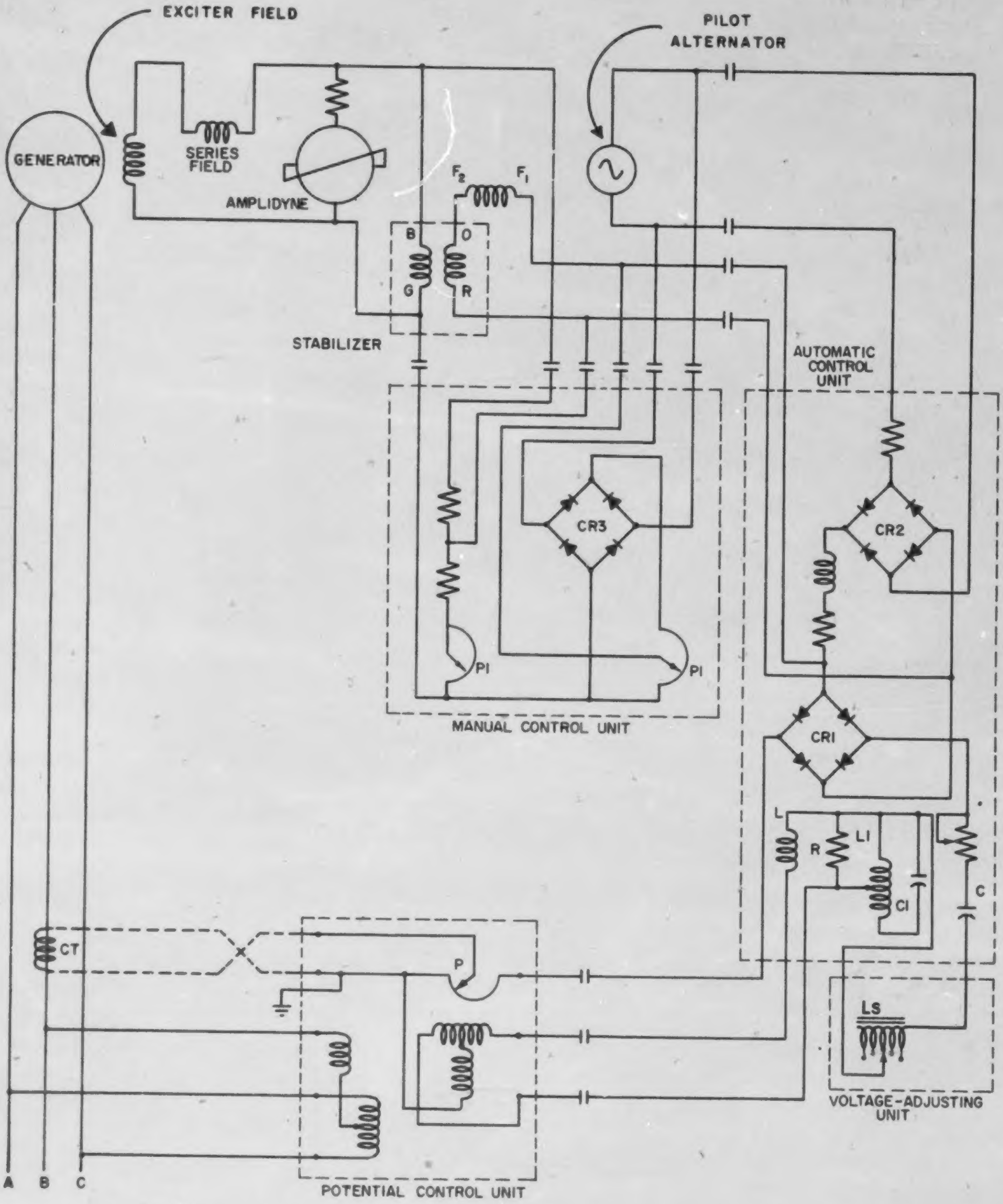
The schematic diagram of an amplidyne voltage regulator installation is illustrated in figure 3-9.

The normal operational sequence for a single generator is to set both handwheels of the manual control unit in the extreme LOWER position, turn the regulator cutout switch to MANUAL, and turn the transfer switch to NORMAL; after making certain that the generator circuit breaker is open. Then start the prime mover and bring the generator up to speed. When the generator is up to speed, raise the generator voltage to approximately 450 volts by turning the handwheels of the manual control unit in the RAISE direction and set the handle of the voltage adjusting unit for 450 volts


PILOT ALTERNATOR
STABILIZER PRIMARY
SERIES FIELD
GENERATOR FIELD
GENERATOR
A
B
C
AMPLIDYNE EXCITER
F1
CONTROL FIELD
F2
CR3
STABILIZER SECONDARY
MANUAL CONTROL RHEOSTAT
COARSE ADJUSTMENT
P1
FIXED RESISTANCE VOLTAGE DIVIDER IN MANUAL CONTROL UNIT
MANUAL CONTROL RHEOSTAT FINE ADJUSTMENT
BOOST CIRCUIT
BUCK CIRCUIT

27.34

Figure 3-8.—Manual control circuit.


EXCITER FIELD
PILOT ALTERNATOR
GENERATOR
SERIES FIELD
AMPLIDYNE
F2
F1
B
O
G
R
STABILIZER
AUTOMATIC CONTROL UNIT
CR3
CR2
P1
P1
MANUAL CONTROL UNIT
CR1
L
R
L1
C1
C
CT
P
LS
VOLTAGE-ADJUSTING UNIT
A
B
C
POTENTIAL CONTROL UNIT

111.29

Figure 3-9.—Schematic diagram of amplidyne voltage regulator installation.

corresponding to no-load. Then put the regulator in control of the a.c. generator voltage by turning the cutout switch from MANUAL to AUTOMATIC. Finally, adjust the generator voltage to 450 volts by turning the handle of the voltage adjusting unit and then close the generator circuit breaker.

If the generator is to be operated in parallel with a generator already connected to the bus, close the circuit breaker of the incoming generator only when the two voltages are in synchronism. As soon as the two generators are operating in parallel, readjust the governors of the prime movers until each unit takes its share of the kW load and then equalize the power factors of the machines by means of the voltage adjusting units. When the kW loads and power factors on the generators are equal, the current of each generator should also be equal.

If the system voltage is high after the power factors are balanced, slowly turn the voltage adjusting units of both generators in the lower direction until the system voltage is approximately 450 volts. If the system voltage is low, slowly turn the voltage adjusting unit of both generators in the raise direction until the system voltage is approximately 450 volts.

To remove an alternator from the line, first remove the load by adjusting the governor while observing the wattmeter. When the kW load approaches zero, reduce reactive load with the voltage adjusting unit. Then, trip the alternator's circuit breaker. After the generator is off the line, check to see that the manual control unit is set to the mark for 450 volts corresponding to no load. Then, shift the voltage regulator from AUTOMATIC to MANUAL. Next, turn the manual control in the lower direction.

Maintenance

The maintenance instructions for a specific rotary amplifier regulator given in the MRC and 3-M instructions shall take precedence over other procedures. However, the articles concerning care of rotating electrical machinery in chapter 9610 of *NavShips Technical Manual* shall be observed in all cases where they do not conflict with the MRC, 3-M, or manufacturer's instructions.

The amplidyne's short-circuiting brushes should be checked periodically, as improper brush contact may result in an excessively high amplidyne voltage output.

STATIC EXCITATION AND VOLTAGE REGULATION SYSTEM

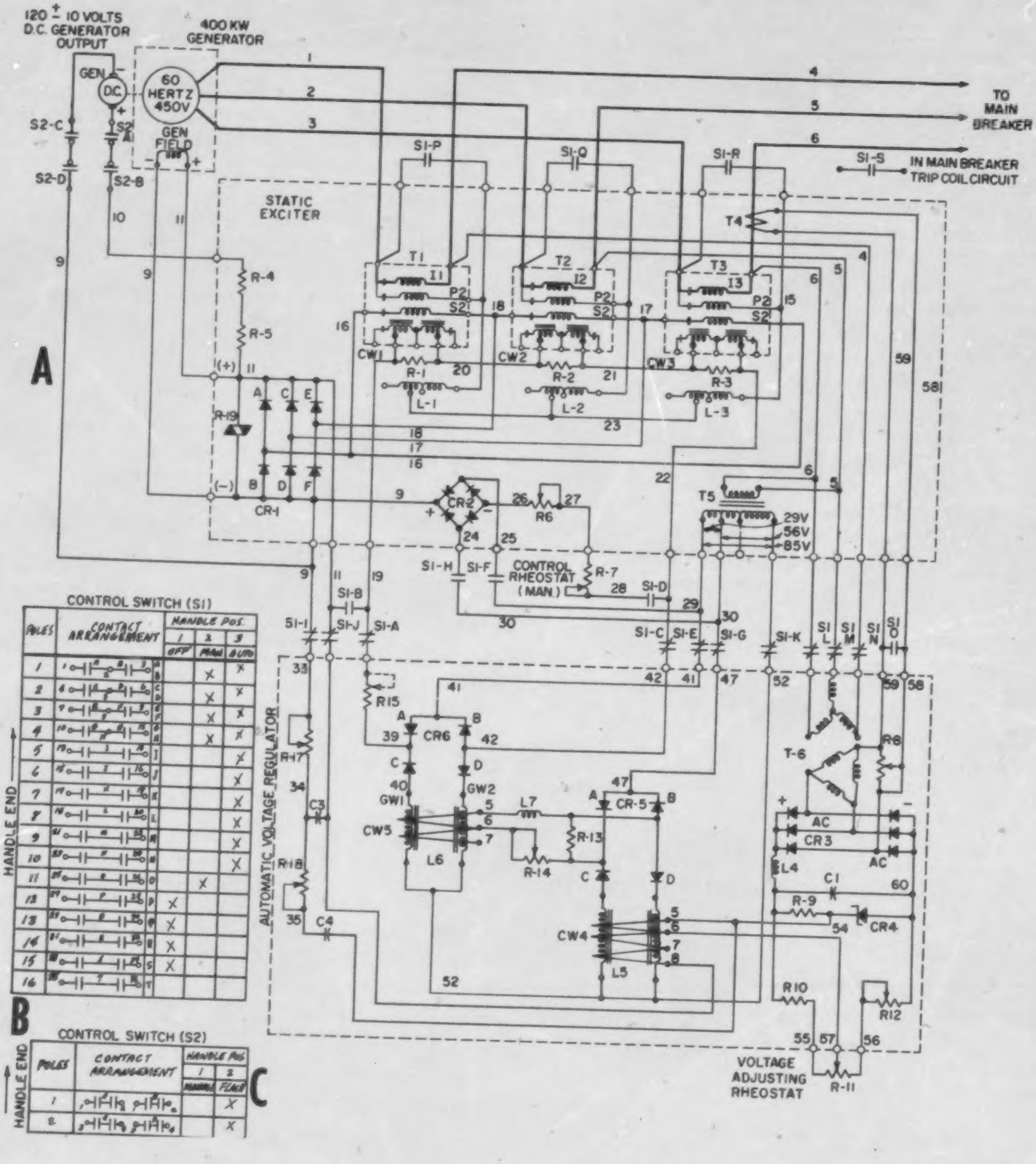
The static excitation voltage regulator system furnishes the a.c. generator field current by rectifying a part of the a.c. generator output. After the a.c. generator has built up some output with the aid of d.c. switched temporarily to the field from a field flashing power source such as a d.c. generator or battery, an automatic voltage regulator controls the output of a static exciter to supply the necessary field current.

The schematic of a static excitation and magnetic amplifier type voltage regulator system is illustrated in figure 3-10. The system provides field excitation and manual and automatic control for the 400-kW, 450-volt, 3-phase, 60-hertz generators.

The control switch (S1) in figure 3-10B has three positions (OFF, MANUAL, and AUTOMATIC). The setting of this switch determines the type of operation to be used. The OFF position can be used to quickly deenergize the generator in case of an emergency. With the switch in this OFF position, four sets of contacts (sets P, Q, R, and S) are closed. Contacts P, Q, and R thereby "short circuit" the potential winding of three potential transformers, respectively identified as T1, T2, and T3 in figure 3-10A to remove rectified current from the exciter. Concurrently, S contact (upper right, Fig. 3-10A) functions to trip the main breaker.

An analysis of the contact arrangement (fig. 3-10B) in switch S1 shows 64 contact-elements are placed (four per pole) on 16 poles. The first four poles produce 8 single-pole-single-throw switches (each SPST identified by 8 letters, A through H). These 8 have 12 terminals (identified further by 12 numbers, 1 through 12).

The fifth pole (No. 5 in fig. 3-10B) has only two numbered terminals (13 and 14) to identify switch section I, where its two SPST switches are arranged in series. The function of this series


120 ± 10 VOLTS
D.C. GENERATOR
OUTPUT
400 KW
GENERATOR
GEN
D.C.
60
HERTZ
450V
GEN
FIELD
S2-C
S2-A
S2-D
S2-B
STATIC
EXCITER
TO
MAIN
BREAKER
SI-S
IN MAIN BREAKER
TRIP COIL CIRCUIT
SI-P
SI-Q
SI-R
T1
T2
T3
T4
T5
I1
I2
I3
P2
S2
CW1
CW2
CW3
R-1
R-2
R-3
L-1
L-2
L-3
R-4
R-5
R-19
CR-1
CR2
R6
SI-H
SI-F
CONTROL
RHEOSTAT
(MAN.)
R-7
SI-D
SI-B
SI-I
SI-J
SI-A
SI-C
SI-E
SI-G
SI-K
SI L
SI M
SI N
SI O
29V
56V
85V
AUTOMATIC VOLTAGE REGULATOR
R15
CR6
GW1
GW2
CW5
L6
L7
R-13
R-14
CR-5
CW4
L5
R17
R18
C3
C4
T-6
R8
AC
CR3
L4
C1
R-9
CR4
R10
R12
VOLTAGE
ADJUSTING
RHEOSTAT
R-11
A
B
C

CONTROL SWITCH (S1)

POLES	CONTACT ARRANGEMENT	HANDLE POS. 1 OFF	HANDLE POS. 2 MAN	HANDLE POS. 3 AUTO
1	A B		X	X
2	C D		X	X
3	E F		X	X
4	G H		X	X
5	I			X
6	J			X
7	K			X
8	L			X
9	M			X
10	N			X
11	O		X	
12	P	X		
13	Q	X		
14	R	X		
15	S	X		
16	T			

HANDLE END

CONTROL SWITCH (S2)

POLES	CONTACT ARRANGEMENT	HANDLE POS. 1 MANUAL	HANDLE POS. 2 FLASH
1			X
2			X

HANDLE END

111.30

Figure 3-10.—Elementary diagram of static excitation voltage regulator system.

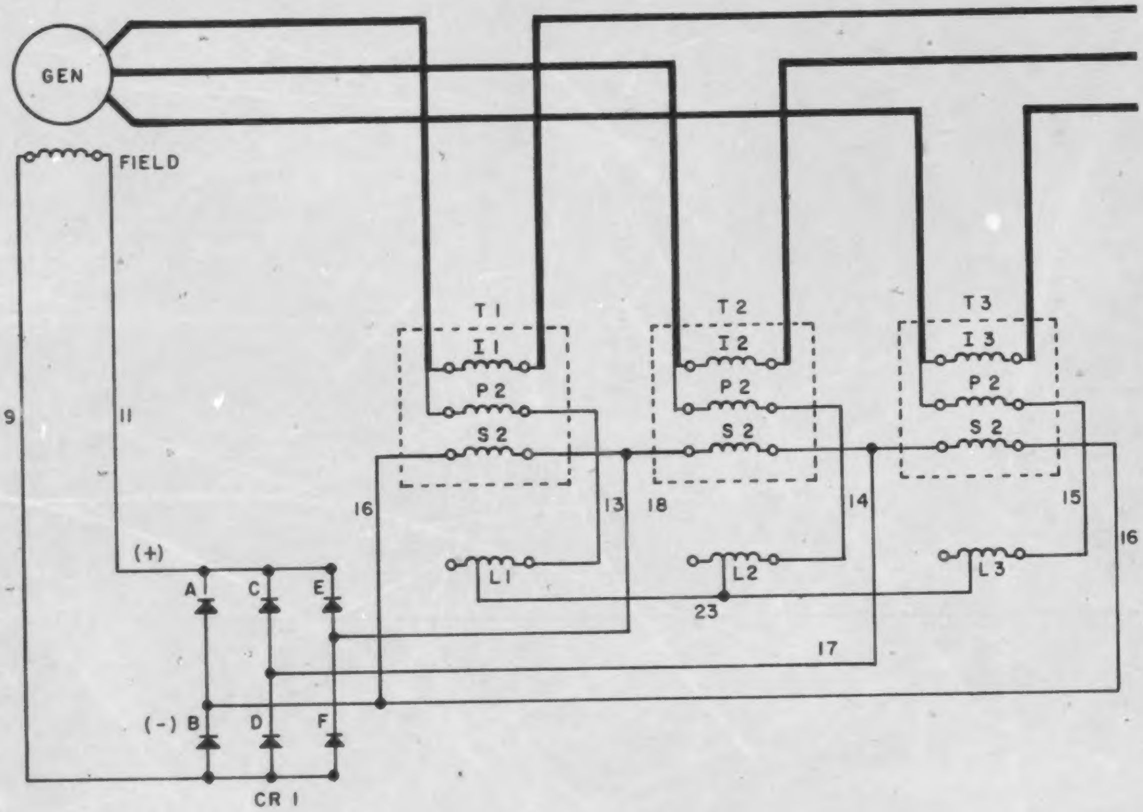
arrangement is twofold: First, to provide several contacts that open fast and wide to quickly quench the several arcs produced (in an inductive-reactance circuit) during the OFF "break" of the switching action. Second, to provide optimum cooling of heated contacts that become hot from arcing.

Each remaining (eleven) pole of switch S1 also is arranged with series assemblies like switch section 1. They are identified by letters J through T, with their terminals numbered 15 through 36. Switch section T is a spare. The letter X denotes those contacts that are closed when the switch is put into a selected position of OFF, MANUAL, or AUTOMATIC. S1 is shown in the AUTOMATIC position in figure 3-10A.

Switch S2 is an assembly of 16 contact elements (fig. 3-10C) which are connected in series to produce 8 switches, which operate simultaneously to function as a single ON-OFF device. Again, the function (using many switches) serves to break a long arc into several smaller arcs for producing long life from several heat-dissipating contacts.

STATIC EXCITER

The static exciter (fig. 3-11) consists of a 3-phase rectifier, CR1, three linear inductors, L1, L2, L3, and three transformers, T1, T2, T3.



111.31

Figure 3-11.—Static exciter.

The transformers are alike and interchangeable. Each transformer contains 4 windings but figure 3-11 shows only the three windings that perform in the basic exciter circuits; one is the potential or primary (P2) winding, the secondary (S2) winding, and the current winding. The remaining control winding is discussed later. Briefly, each transformer is identified as an SCPT (saturable current potential transformer).

The primary winding of T1, T2, and T3 are Y-connected through the linear inductors L1, L2, and L3 by conductors 13, 14, 15, and 23.

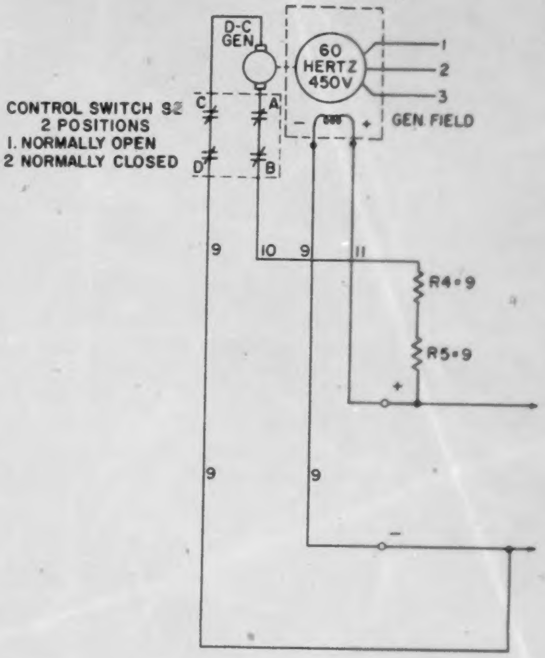
The secondary winding is delta connected to diodes (A, B, C, D, E, and F) of rectifier CR1 by means of conductors 16, 17, and 18. These elements comprise a 3Ø full-wave bridge rectifier that delivers d.c. to conductors No. 11 and No. 9 which supply the generator field.

The current in the control windings CW1, CW2, and CW3 (fig. 3-10A) controls the output of the SCPT secondaries and thus the output of the static exciter. The control windings are supplied by the voltage regulator output as discussed later. Load current flowing in the current windings (I1, I2 and I3 in fig. 3-10A) compensates for changes in the generator load.

Field Flashing Circuit

Since the static exciter cannot supply field current until some a.c. voltage has built up in the 400-kW generator, d.c. power is temporarily provided by a 50-kW d.c. generator delivering 120 volts.

To start the system the spring-return field flashing switch, S2 (fig. 3-10C), should be moved to the FLASH position. The control switch, S1, may be placed in either the MANUAL or AUTOMATIC position. This allows flashing current to flow temporarily to the field of the a.c. generator, as shown in figure 3-12, when the prime mover is started and the generator is brought up toward its rated speed. Switch S2 should be released as soon as the generator voltage begins to build up because thereafter the static exciter (fig. 3-11) is capable of continuing the d.c. flow required by the generator field.



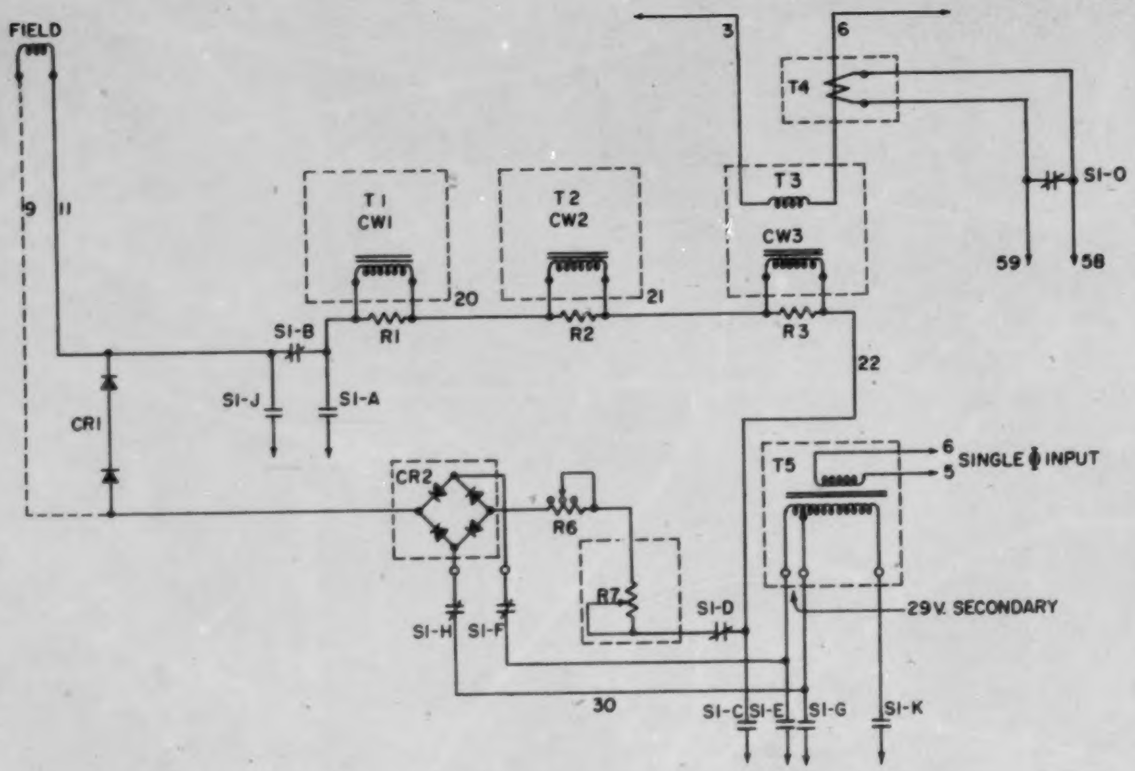
111.32

Figure 3-12.—Field flashing circuit.

The field does not have to be flashed every time the system is placed in operation. It is usually necessary to flash the field only after a generator malfunction or when the generator is idle for long periods of time, such as overhaul periods.

Manual Voltage Control Circuit

With switch S1 (fig. 3-13) in the manual position, contacts F and H are closed connecting the 29 volt secondary of transformer T5 to the bridge rectifier CR2. The resulting d.c. leaves CR2 from its negative terminal, flows by way of resistor R6, manual control R7, and closed switch S1-D to conductor No. 22. This direct current flow continues through the series arrangement of each SCPT control winding,



111.33

Figure 3-13.—Manual voltage control circuits.

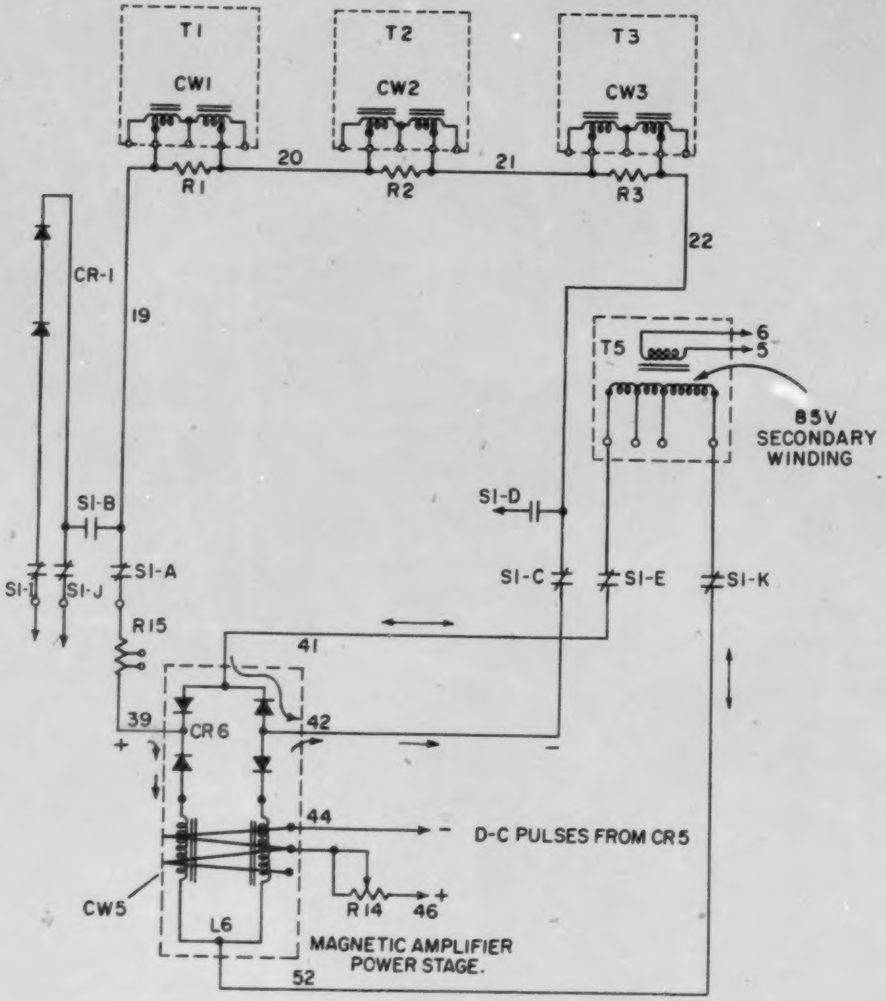
combines temporarily with the flow of the generator's d.c. field passing from + to - of rectifier CR1, and terminates at the positive terminal of rectifier CR2.

Five switch sections of S1 are closed to establish manual control of the exciter's output: namely B, D, F, H, and O. Switch S1-O short circuits the output of transformer T4 to eliminate a drooping characteristic which is not now required. Manual operation is achieved by regulating resistor R7, which functions to vary the saturation of the cores of T1, T2, and T3. Varying the amount of direct current alters the core saturation and those variations will change the voltage value that is induced from each primary into its associated secondary winding shown in figure 3-11.

AUTOMATIC VOLTAGE REGULATOR

The static exciter alone (fig. 3-11) will not maintain the different amounts of field current required to maintain a constant value of a.c. voltage at the generator terminals during various load changes.

Therefore, a voltage regulator is needed to hold the generator voltage constant regardless of all changing conditions that tend to alter its uniformity. The automatic regulator controls the exciter output by regulating precisely the flow of d.c. in the control winding of each SCPT (T1, T2, T3 in figure 3-14). Here the initial a.c. is provided by the 85-volt secondary of transformer T5, which feeds rectifier CR6, to provide the d.c. source at terminals 39 and 42.


T1
CW1
T2
CW2
T3
CW3
20
21
R1
R2
R3
22
CR-1
19
T5
6
5
85V
SECONDARY
WINDING
S1-B
S1-D
S1-A
S1-C
S1-E
S1-K
S1-I
S1-J
R15
41
39
CR6
42
+
−
44
D-C PULSES FROM CR5
CW5
R14
46
L6
MAGNETIC AMPLIFIER
POWER STAGE.
52

111.34

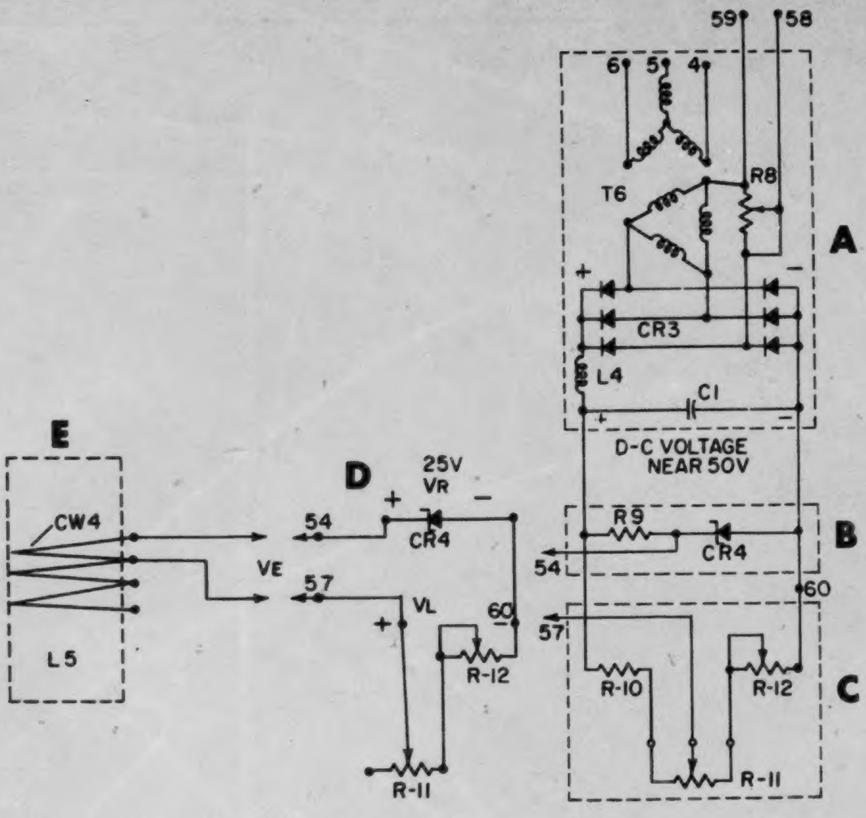
Figure 3-14.—Final stage magnetic amplifier.

The flow of d.c. is precisely controlled by the ohmic reactance values of each coil of L6. The controlled reactance depends on the state of magnetic saturation produced by another regulated d.c. flow from rectifier CR5 (fig. 3-10A).

The control of this regulated output of rectifier CR5 originates with sampling the average of the three line voltages by the sensing circuit in figure 3-15A. This voltage is processed further in the reference and comparison circuits (fig. 3-15B and C) for amplification in the preamplifier of figure 3-16.

Sensing Circuit

To obtain the best regulation during unbalanced load conditions in the three phases, the sensing circuit (fig. 3-15A) which responds



111.35

Figure 3-15.–Automatic voltage regulator.

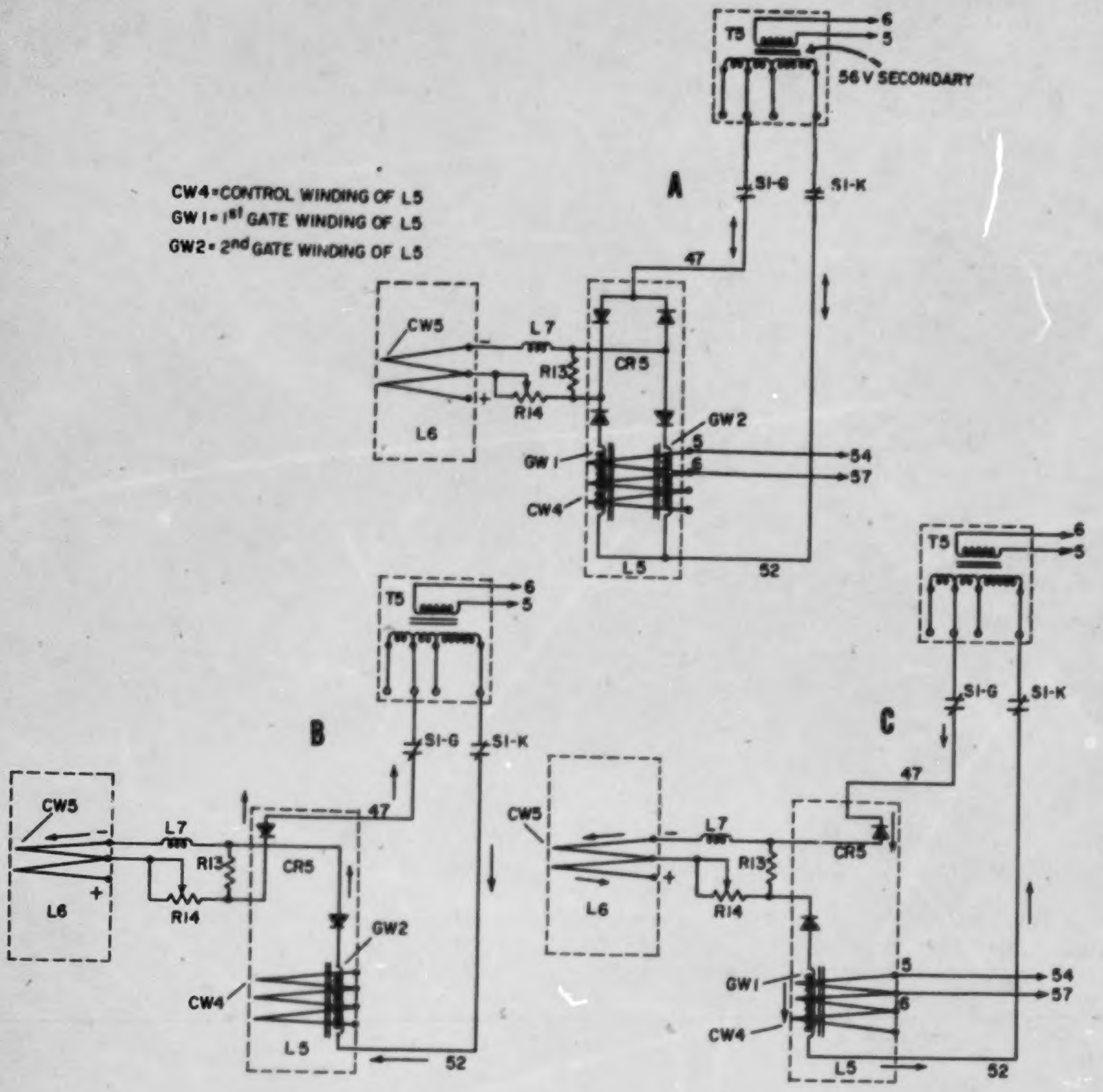
to the average of the three values of a.c. line voltages is used.

Transformer T6 reduces the line voltage of each phase to a convenient value and rectifier CR3 converts the 3-phase a.c. to d.c. voltage. If an unbalanced condition causes the three line voltages to become unequal, the d.c. across the rectifier will have considerable (third harmonic) ripple, but the combined filter actions of inductor L4 and capacitor C1 will remove the ripple and produce d.c. across C1 (near 50 volts) which is always in proportion to the average of the three line voltages.

Resistor R8 is used for reactive droop compensation and will be discussed later.

Reference Circuit

The reference circuit (fig. 3-15B) consists of resistor R9 and rectifier CR4. The function of CR4 is to supply a nearly constant (25 volt) reference voltage to the comparison circuit. Drooping resistor R9 limits the current through CR4 to a safe value. If the voltage (near 50 volts) across R9 and CR4 increases, the current increases in both items, but the voltage increases only across R9 leaving the voltage across CR4 at its original voltage value (25 volts). This is because CR4 is an assembly of four silicon units, each unit operating in the natural breakdown (or Zener) region and having nearly constant 6.2 volt drop across each unit.


CW4 = CONTROL WINDING OF L5
GW1 = 1st GATE WINDING OF L5
GW2 = 2nd GATE WINDING OF L5
A
B
C
T5
6
5
56 V SECONDARY
S1-G
S1-K
47
CW5
L7
R13
R14
CR5
L6
GW1
GW2
CW4
L5
5
6
54
57
52
-
+

111.36

Figure 3-16.—First stage magnetic amplifier.

Comparison Circuit

The comparison circuit consists of the reference circuit (fig. 3-15B) combined with resistors R10, R11, and R12 (fig. 3-15C). Its function is to compare the "average line-voltage" to the reference voltage and to act on the first-stage magnetic amplifier to correct any difference.

Error Voltage

Three sets of tests are made with a d.c. voltmeter at the 3 terminals (numbered 54, 57, and 60) in figure 3-15C and will reveal several facts that explain the ERROR VOLTAGE (V_E) produced across terminals No. 54 and No. 57 (fig. 3-15D).

Connect a d-c voltmeter to the V_E terminals. Disregard meter-polarity connections because, regardless of polarity selections, some of the performance tests will cause the meter to read downscale when the polarity (of the error voltage) reverses.

Initial changes in the amount of V_E are made by adjusting the slider on VOLTAGE ADJUSTING RHEOSTAT R11. A slider position of R11 will be found where V_E registers zero. Then reposition the meter leads to verify that the reference voltage V_R (terminal No. 60 is negative; No. 54 is positive) will always remain at 25 volts regardless of circuit changes. Relocate the meter leads to measure V_L and verify that it has the same value (25 volts) as V_R, for this special measurement only, when V_E is zero. If resistor R11 is readjusted to produce, for example, either a 27- or a 23-volt reading for V_L then V_E has a numerical value of 2 volts but polarities are reversed. When V_L is greater than V_R, a direct current will flow in the control primary winding CW4 of the first-stage magnetic amplifier, and the automatic voltage regulator will reduce the exciter voltage, thereby lowering the line voltage. Conversely, when V_L is less than V_R, the regulator will increase the exciter voltage, thus raising the line voltage.

Magnetic Amplifier Circuits

The essential parts that comprise two stages of magnetic amplifiers (figs. 3-14 and 3-16) consist of L5, CR5, R13, R14, L6, CR6, and R15.

Changes in generator voltage produce changes in current in the comparison circuit which are in the order of milliamperes while flowing in the control winding, CW4 (fig. 3-16). It is necessary to amplify considerably these initial small currents so their effect is in the order of several amperes in the final control windings, CW1, CW2, and CW3 of the SCPTs.

Two magnetic-amplifier gates (GW1 and GW2) function automatically and alternately in figure 3-16 to regulate the flow of a.c. delivered by the 56-volt secondary of transformer T5. The automatic regulation is achieved by saturating and desaturating the flux in the cores of GW1 and GW2. The degree of flux at any moment in each core is determined by the previously described conditions of d.c. flow in the control winding, CW4.

The flow of gated a.c., and its conversion into d.c. pulses in another control winding (CW5 of the power amplifier, L6), is readily traced by inspection of the arrows in figure 3-16B and C. These arrows alongside the conductors and rectifier elements are in the direction of electron flow during one half cycle in figure 3-16B and the other half cycle in figure 3-16C. The control winding current can be changed until the full supply voltage is applied to the load. In this way, a control winding in each stage of the several saturated cores controls the output from the magnetic amplifier.

The ~~series resistors R14~~ (fig. 3-16) and R15 (fig. 3-14) are adjusted so that each amplifier operates in the center of its saturation curve (for the magnetic core materials that are used).

Inductor L7 (fig. 3-16) is used to assure smooth continuous control of the second stage amplifier.

Transformer T5 is used to supply a.c. power to the two magnetic amplifiers. It is also used to supply control current when it is operating in manual control.

A control winding would function to change its flux by means of either "d.c. pulses" or "filtered d.c." Control winding CW4 employs filtered d.c. by virtue of using capacitor C1 in the sensing circuit.

If, in figure 3-16B, the supply voltage (from transformer T5) is applied to the gate winding in series with its CW5 load, most of the voltage drop is across the gate winding (and very little voltage drop is across the CW5 control-winding load) provided the flux in the L5 core never reaches saturation. If the control-winding CW4 current is now changed so that the core flux reaches saturation for part of the cycle, the gate-winding inductance drops to a very low value for that part of the cycle and a portion of the supply voltage wave is applied to the load.

Stabilizing Circuit

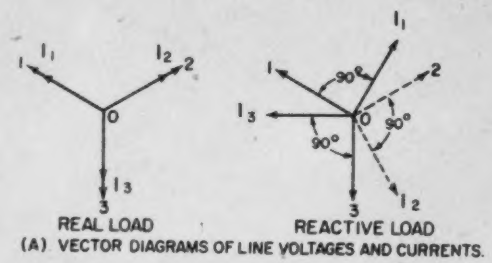
In any closed-loop regulating system containing several time constants and having high gain, sustained oscillations would be produced. These undesired oscillations are sometimes called HUNTING. To prevent hunting, a stabilizing filter circuit (resistor R17 and capacitor C3 in fig. 3-10A) removes the normal ripple from the exciter output voltage and another network (resistor R18 and capacitor C4) stabilizes the exciter output voltage.

The nonlinear resistor, R19, is used to suppress abnormally high transient voltages that may appear across the field rectifier, CR1.

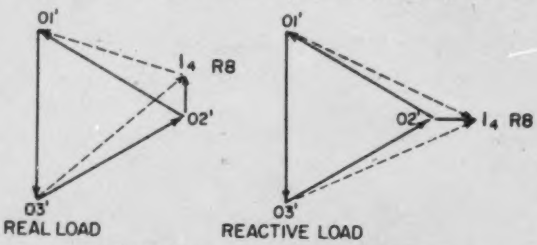
Reactive Droop Compensation Circuit

Current transformer T4 and resistor R8 are used to obtain the generator drooping characteristic. The vector diagrams for this circuit are shown in figure 3-17A and B. Figure 3-17A shows the line voltages and currents for real and reactive loads. Figure 3-17B shows the voltages on the secondary of the transformer T6, along with the IR (voltage) drop (produced across resistor R8 due to its "current from the secondary, T4," called I4). For an in-phase, real load this "I4 R8" voltage drop shortens vector 01' but lengthens vector 02' (dashed lines) and the average of the three vectors remains essentially constant. However, for reactive load the "I4 R8" voltage drop lengthens vectors 01' and 02' (dashed lines) and increases the average of the three vectors.

The regulator senses this higher voltage and thereby reduces the generator voltage, by giving the generator a drooping characteristic for reactive load.



(A) VECTOR DIAGRAMS OF LINE VOLTAGES AND CURRENTS.



(B) VECTOR DIAGRAMS OF VOLTAGES AND CURRENTS FOR T6 & T4

111.37

Figure 3-17.—Vector diagrams of reactive droop circuit.

Since the average of the three vectors 01', 02', and 03' did not change for real load, the generator should remain essentially constant.

The amount of reactive droop can be increased by increasing the resistance of resistor R8.

PARALLEL OPERATION

Before connecting an a.c. generator in parallel with another machine for the first time, make a check of the reactive droop compensation circuit and check the prime mover instructions on parallel operation. Make the same test for both generators.

Deenergize the generator by stopping it or by turning switch S1 to the EMERGENCY or OFF position. Check the resistance of R8 and be certain its resistance is 2 ohms or more. Start the generator again, flash the field, and adjust the voltage adjusting rheostat for rated voltage with switch S1 in the AUTO position.

To check the polarity of the reactive droop circuit, note the terminal voltage of the generator at no load on automatic control.

Then, add a lagging reactive load to the generator and again note the generator voltage. It SHOULD DECREASE. If the voltage rises, shut down the system and reverse the leads to the secondary of the current transformer.

Set resistor R8 so that the voltage decrease is the same for both generators and is not more than 4 percent of the nominal voltage when reactive load is applied. Set the same terminal voltage on the two generators, and check to see that the phase rotation is the same for both generators. Parallel the generators after they have been properly synchronized.

MANUAL OPERATION

To start the equipment, set the manual control rheostat R7 for minimum volts (fully counterclockwise). Set the control switch S1 on MANUAL. Next hold the FLASHING switch S2 in the FLASH position until the generator starts to build up. Then adjust the manual control rheostat R7 to obtain the proper generator voltage. The system is now operating in MANUAL.

AUTOMATIC OPERATION

To operate the system in AUTOMATIC, turn the control switch S1 to the AUTO position and adjust the voltage regulating rheostat R11 to obtain the proper voltage.

The control switch S1 should never be left in an intermediate position between MANUAL and AUTOMATIC.

The control switch S1 has an emergency shutdown feature when placed in its OFF position. This can be used to quickly deenergize the generator in case of an emergency.

MAINTENANCE

The static regulator has no moving parts and its components are extremely rugged, therefore, little maintenance besides preventive maintenance is required.

Regular preventive steps must be assured by checking equipment for cleanliness and all connections for tightness.

Protecting all parts from moisture is essential, especially where selenium rectifiers are concerned. Although treated to stop destruction by moisture, continued exposure to moisture or mercury compounds tends to destroy selenium cells.

In replacing new rectifier units in CR4, 5, or 6 it is important not to overheat their leads when soldering. To prevent this, use a low temperature solder (resin core) and attach a small "heat sink" such as an alligator clip or grip with long nose pliers between the rectifier and the attached lead where the soldering is done. This will prevent damaging heat reaching the rectifier cell.

If it is necessary to apply a hipot (high-potential) test with megger or other devices to exciter or generator, all rectifiers must be shorted out with clip leads. High-potential tests are discussed in chapter 9600, *NAVSHIP'S Technical Manual.*

CHAPTER 4

TRANSISTORIZED CONTROL DEVICES

More and more, semiconductors are replacing electron tubes, magnetic amplifiers, and other such devices used in electrical equipment. Some of the semiconductor devices used in shipboard electrical equipment are silicon controlled rectifiers, junction diodes, zener diodes, triode transistors, and unijunction transistors.

You must thoroughly understand semiconductors before you attempt any work on equipment that uses them. Technical manuals on electrical equipment using semiconductor devices do not always include detailed information on semiconductors. In addition to this text, there are two excellent references which describe the theory and operation of semiconductor circuits in all types of electronic equipment—*EIMB Handbook: Electronic Circuits*, NSN 0967-LP-000-0120, and *Basic Electronics*, NAVEDTRA 10087-C.

This chapter is a basic treatment of semiconductors. We shall discuss three representative examples of transistorized systems—ship's service generator exciter-regulator type SB-SR, SPR-400 line voltage regulator, and synchronizing monitor. You may have no knowledge of semiconductor circuits, or you may have attended a service school where these circuits were taught. In any event, when you complete your study of this material, you should have the necessary background to analyze, repair, or direct the maintenance of any similar system.

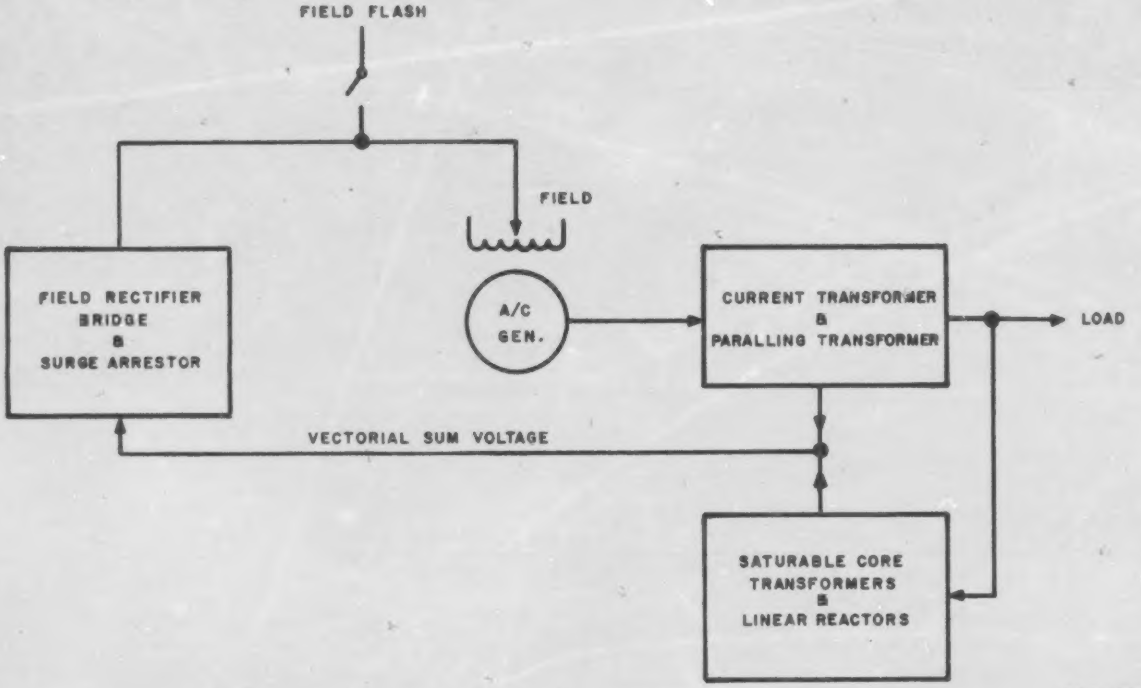
SHIP'S SERVICE GENERATOR EXCITER-REGULATOR TYPE SB-SR

The ship's service generator exciter-regulator type SB-SR controls the generator voltage by controlling the amount of current delivered to the generator field. The exciter-regulator senses the generator voltage and compares a rectified sample of that voltage to a reference voltage. The resultant error signal is amplified by a transistorized differential amplifier to energize the control windings of a magnetic amplifier. The magnetic amplifier output controls the conduction time of two SCR (silicon controlled rectifier) thyristors which in turn control the degree of saturation of the saturable transformers and thereby control their output. The saturable transformers receive their output power from the generator voltage. The current transformers are connected in series with the generator terminals and the load; their output is determined by the load. The output of the current transformers, together with the output of the saturable transformers, is applied to the field rectifier bridge. The vector summation of these two outputs determines the generator field current and thereby the generator output voltage. The exciter-regulator consists of two functional sections, the exciter and the voltage regulator.

EXCITER

The exciter contains three current transformers; three saturable transformers; three linear reactors; a three-phase, full-wave field rectifier bridge; a field flashing system; a surge arrestor; and a paralleling current transformer. The voltage developed at the field rectifier bridge is the vector sum of the saturable transformer, linear reactor, and the current transformer secondary voltages.

Figure 4-1 is a block diagram of the exciter. During no load conditions, no current flows through the current transformer primary,


FIELD FLASH
FIELD
FIELD RECTIFIER BRIDGE & SURGE ARRESTOR
A/C GEN.
CURRENT TRANSFORMER & PARALLING TRANSFORMER
LOAD
VECTORIAL SUM VOLTAGE
SATURABLE CORE TRANSFORMERS & LINEAR REACTORS

111.160

Figure 4-1.–Exciter (Block Diagram).

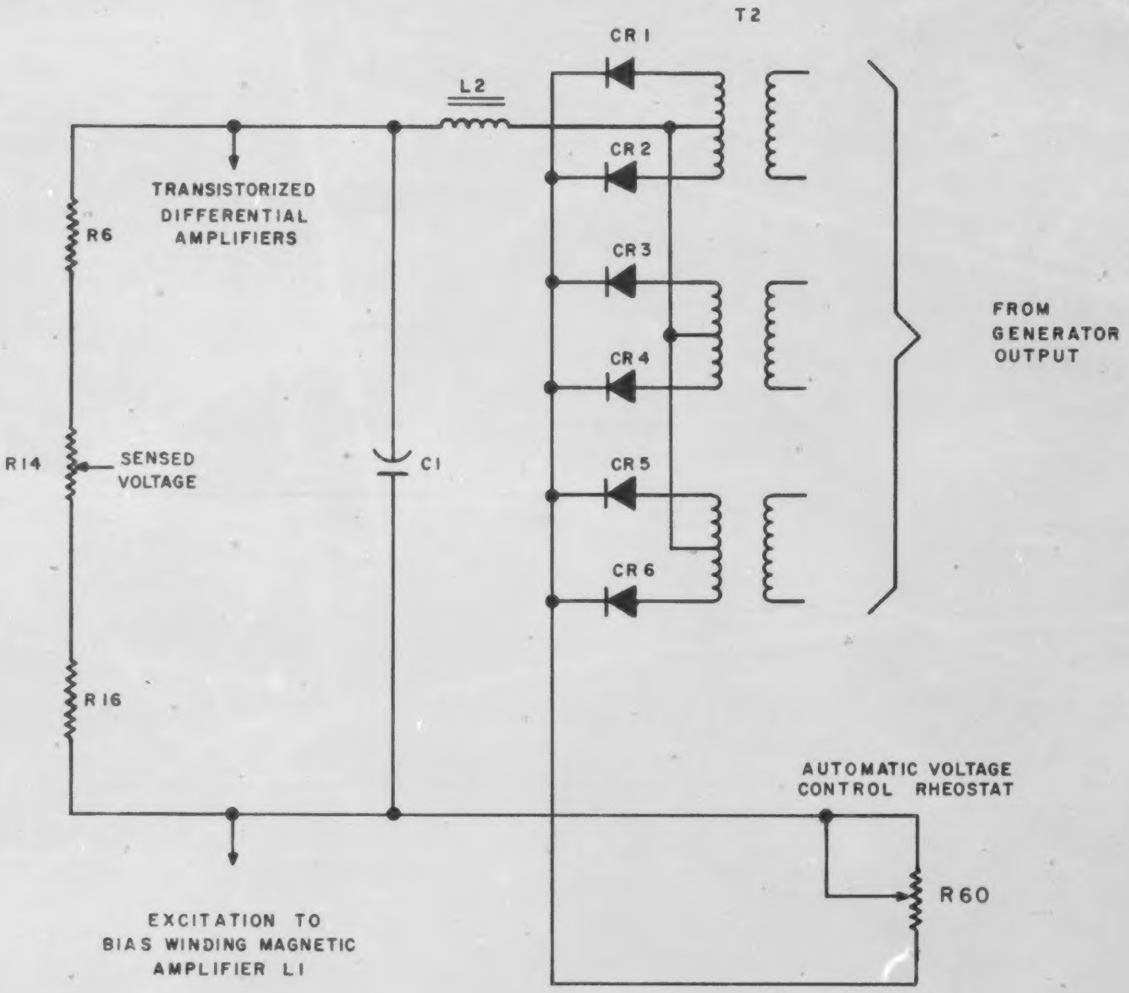
therefore, making no contribution to the excitation of the generator field. At this time, the saturable transformer and the linear reactor furnish the necessary power to excite the generator through the field rectifier bridge. When a load is applied to the generator, synchronous reactance develops within the generator tending to lower the terminal voltage. At this time, the current transformer, in series with the load, develops a voltage proportional to the load. This voltage, combined with the voltage developed by the saturable transformer, is supplied to the field rectifier bridge. The increased output to the field tends to increase terminal voltage. This system would seem ample but, due to the effects of change in ambient temperatures, changes in field resistance, and other non-linear factors, the generator and the exciter can never be matched exactly. A d.c. control current winding in the saturable transformer provides a means of compensating for the mismatch. The amount of d.c. current through this winding determines the degree of saturation of the transformer core. The degree of saturation determines its output which, combined with the current transformers, controls generator terminal voltage. The d.c. current for this winding is produced by the second portion of this system, the voltage regulator.

VOLTAGE REGULATOR

The voltage regulator supplies and controls the d.c. current to the control winding of the saturable transformer. To accomplish this, a combination of circuits and devices are designed to (1) sense terminal voltage, (2) amplify and compare the signal with a reference voltage, (3) rectify and send the signal to saturable transformers, and (4) stabilize the regulator.

Sensing Circuit (Figure 4-2)

The generator voltage is sensed by a step-down, three-phase, sensing transformer (T2), rectified by diodes CR1, CR2, CR3, CR4,


T2
CR 1
L2
CR 2
TRANSISTORIZED DIFFERENTIAL AMPLIFIERS
R6
CR 3
FROM GENERATOR OUTPUT
CR 4
R14
SENSED VOLTAGE
C1
CR 5
CR 6
R16
AUTOMATIC VOLTAGE CONTROL RHEOSTAT
R60
EXCITATION TO BIAS WINDING MAGNETIC AMPLIFIER L1

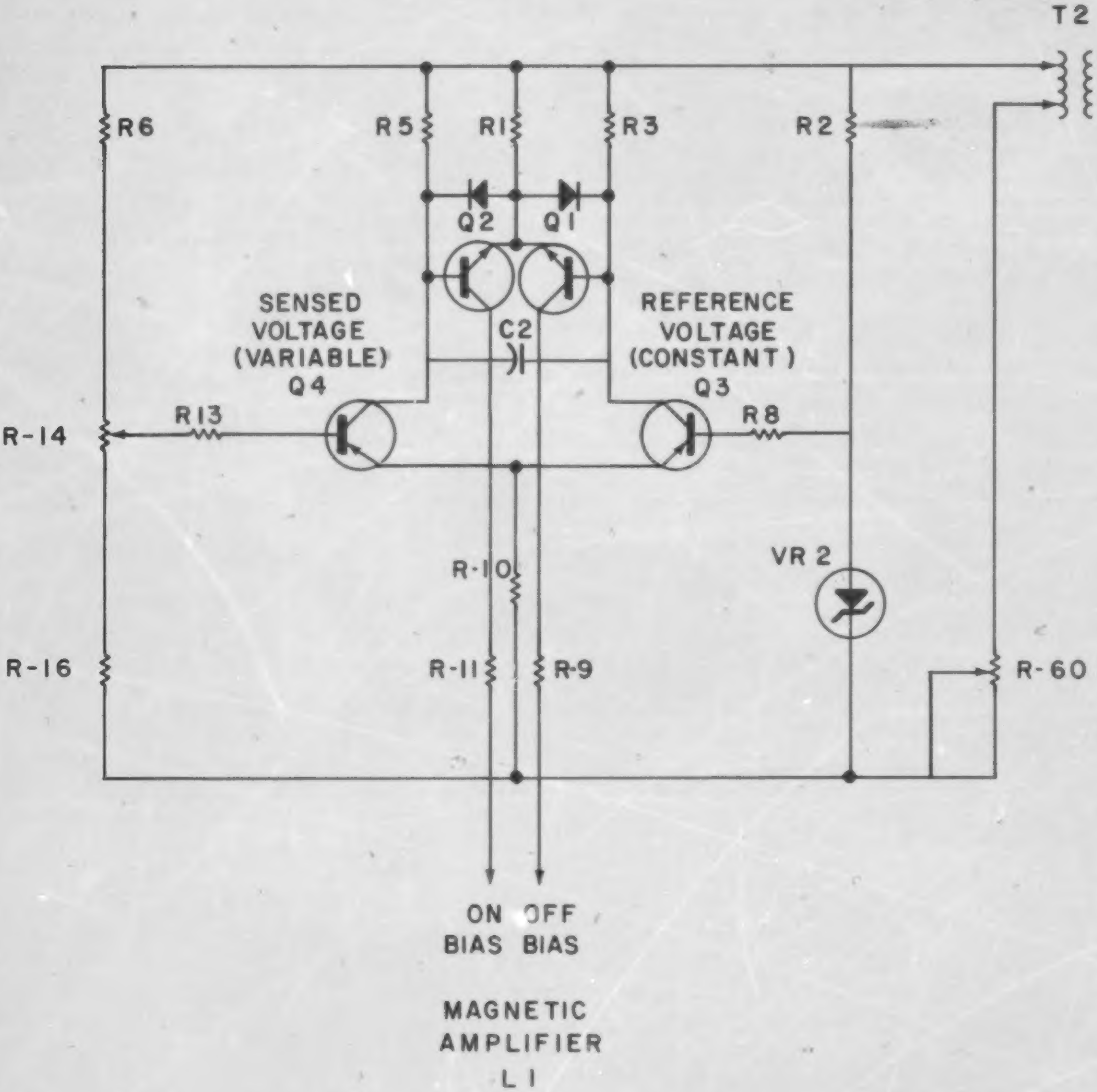
111.161

Figure 4-2.—Sensing Circuit.

CR5, and CR6, filtered by choke L2 and capacitor C1, and applied through external voltage adjust rheostat R60 to voltage divider network resistors R6, R14, and R16. The d.c. sensing voltage also provides power for the two transistorized differential amplifiers and excitation for the bias windings of a magnetic amplifier L1.

Amplifier and Reference Circuit (Figure 4-3)

Transistors Q1, Q2, Q3, and Q4 and their associated circuitry form a two-stage differential amplifier. Transistors Q3 and Q4 amplify the error signal and apply it to transistors Q1 and Q2. Temperature compensated reference Zener


T2
R6
R5
R1
R3
R2
Q2
Q1
SENSED VOLTAGE (VARIABLE)
Q4
C2
REFERENCE VOLTAGE (CONSTANT)
Q3
R13
R8
R-14
R-10
VR 2
R-16
R-11
R-9
R-60
ON BIAS
OFF BIAS
MAGNETIC AMPLIFIER
L1

111.162

Figure 4-3.–Amplifier and Reference Circuit.

diode VR2 maintains the base of transistor Q3 at a constant voltage and is the BASIC REFERENCE POINT in the voltage regulator. When the generator is at rated voltage, the base of transistor Q4 is maintained at approximately the same voltage as the base of Q3 by the tap of potentiometer R14. The collector of Q1 supplies current to the off-bias control winding of magnetic amplifier L1. The collector of Q2 supplies current to the on-bias winding of L1.

Now that you are familiar with the sensing circuit and the amplifier and reference circuit, let us discuss, in the next two paragraphs, steady state voltage and variable voltage as related to these two circuits.

During a steady state load condition, approximately equal voltages are applied to the bases of Q3 and Q4 and therefore the same collector current flows through transistors Q1 and Q2 to the on and off bias windings of L1, cancelling their effect. Magnetic amplifier L1 (fig. 4-4) is a self-saturating device and, when no current flows through its bias windings, its gate winding provides a minimum impedance, resulting in maximum output. However, another off-bias winding (terminals 8 and 9) is biased in the off direction to a point which maintains L1 at approximately one-half its maximum output. This off-bias winding receives its power from a regulated source, reference Zener diode VR1.

As shown in figure 4-5, if the generator voltage begins to decrease, the voltage from T2 that is developed across the divider network R6, R14, and R16 will also decrease, making the base voltage of Q4 less negative, causing its collector current to decrease. Transistors Q3 and Q4 have a common emitter resistor R10 and a decreasing current through Q4 results in less voltage drop across R10. The base voltage of Q3 is held constant by Zener diode VR2, but its emitter voltage is lowered by the voltage drop across R10, causing an increase in the current flow through Q3. A similar action takes place in the other differential amplifier stage which contains transistors Q1 and Q2. The overall result is that the current supplied by Q2 to the on-bias winding (terminals 5 and 6) of L1 decreases, and the current supplied by Q1 to the

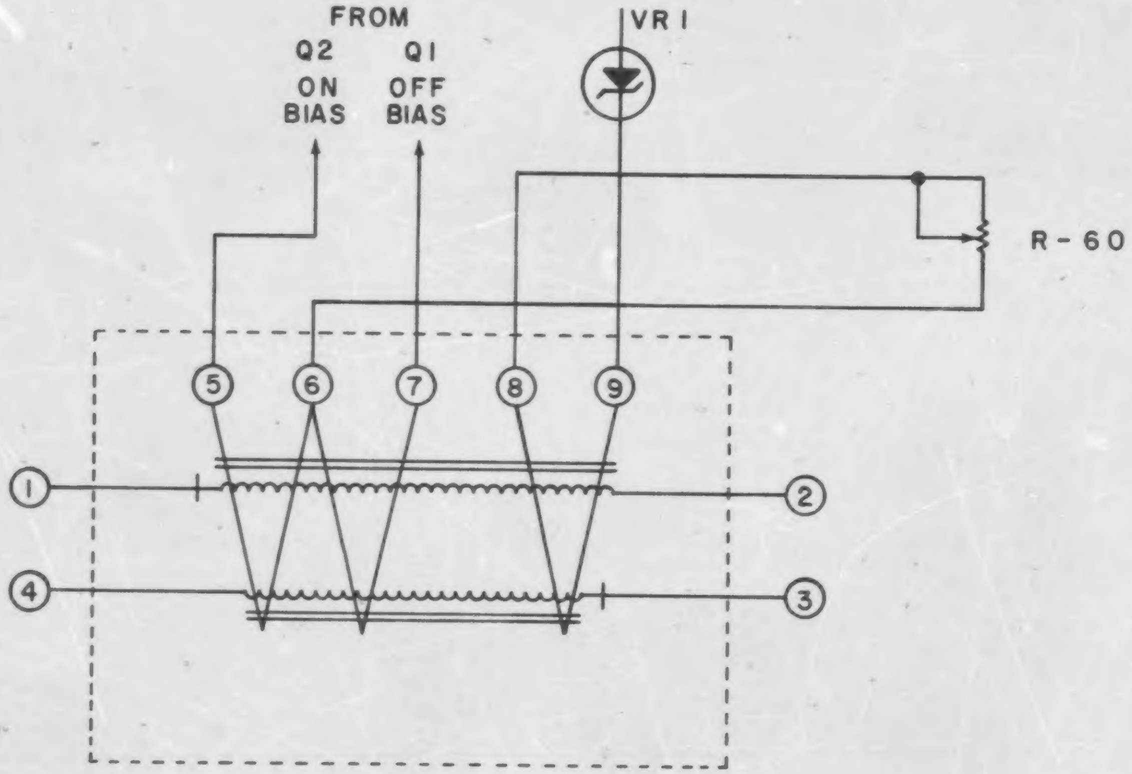


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Figure 4-4.—Magnetic Amplifier L1.

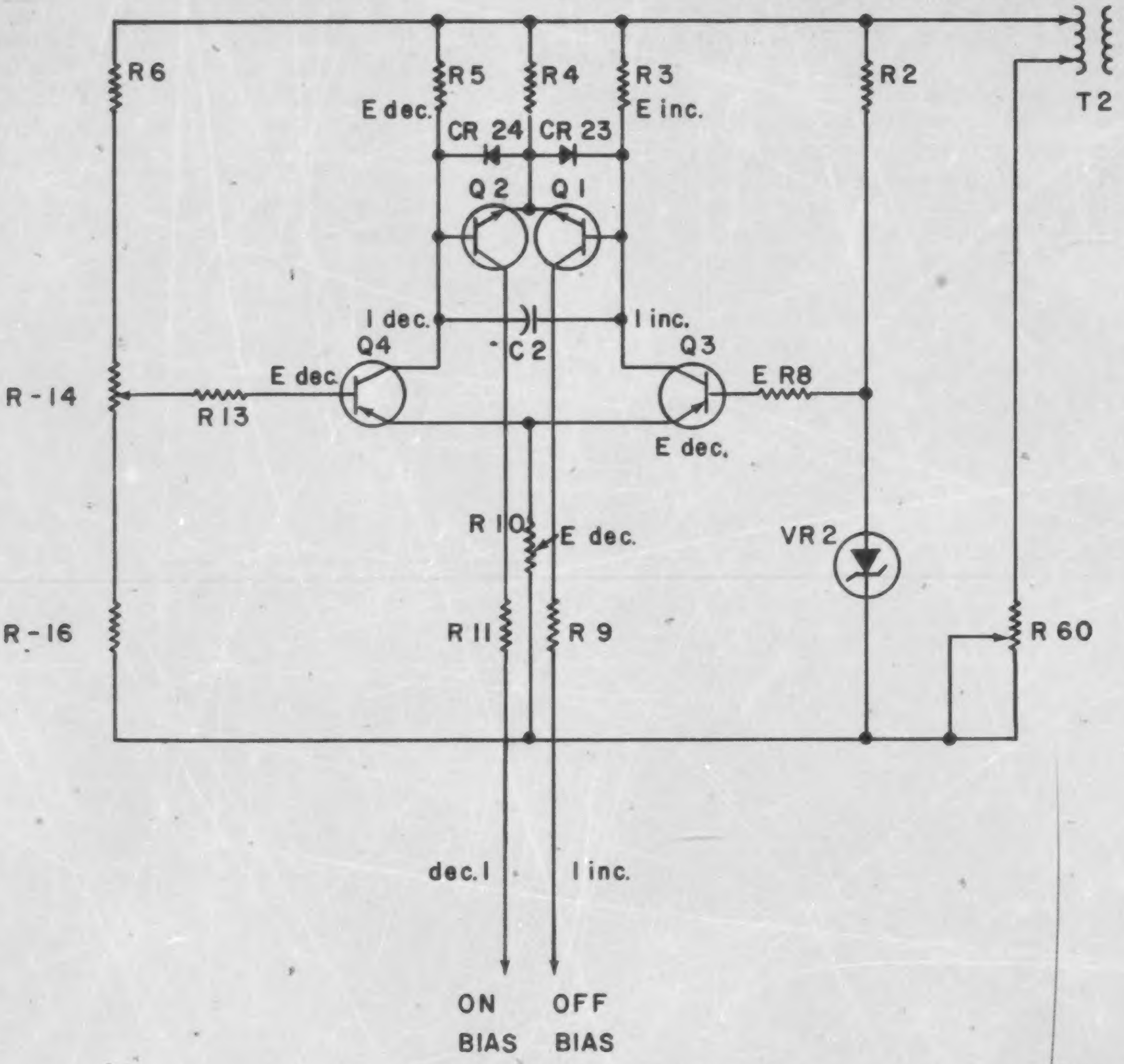
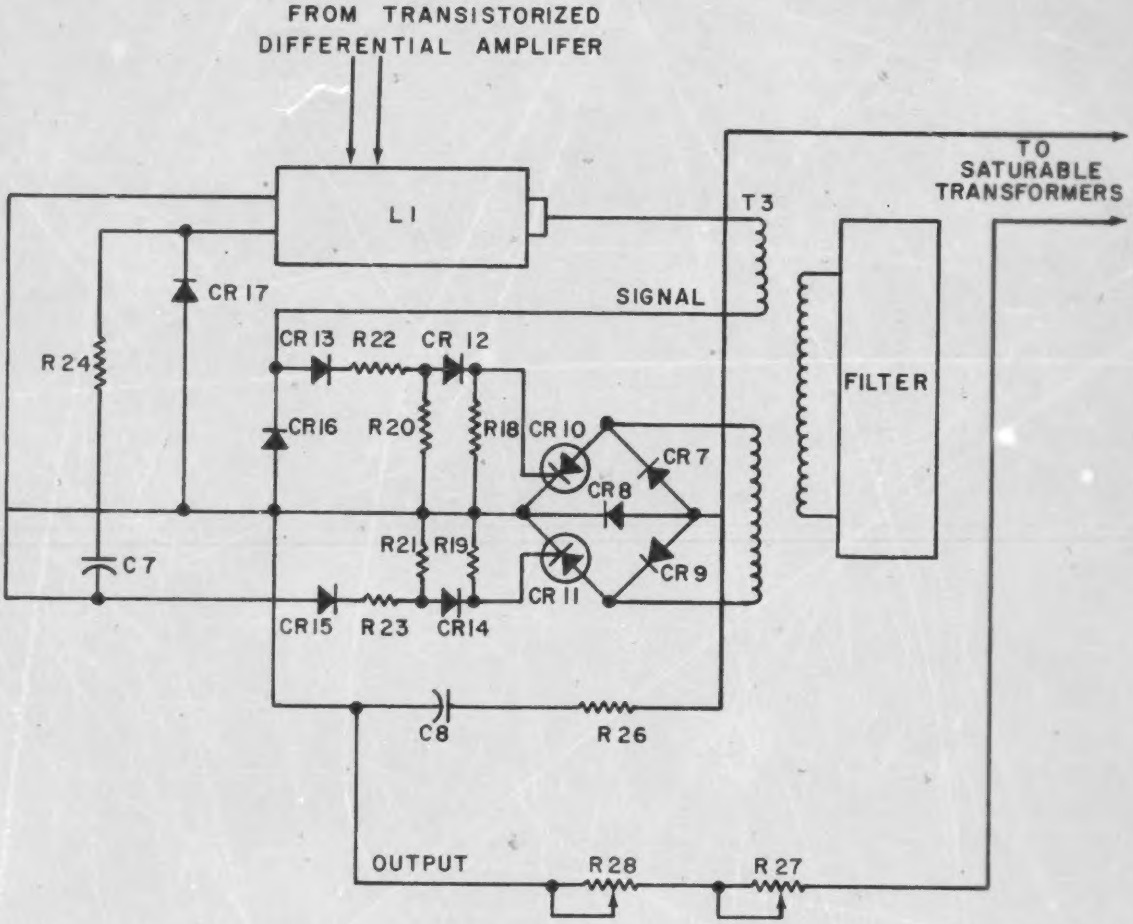

R6
R5
R4
R3
R2
T2
E dec.
E inc.
CR 24
CR 23
Q2
Q1
I dec.
I inc.
Q4
C2
Q3
E dec.
E R8
R-14
R13
E dec.
R10
E dec.
VR2
R-16
R11
R9
R60
dec. I
I inc.
ON BIAS
OFF BIAS

Figure 4-5.–Transistorized Differential Amplifier. (showing voltage decrease sensed at T2) **111.164**

off-bias winding (terminals 6 and 7) of L1 increases. As more off-bias is applied to L1, its input to the rectifier circuit decreases. If the generator voltage increases, the action just described is reversed.

Rectifier Circuit (Figure 4-6)

Power transformer T3 supplies power for the operation of the automatic rectifier bridge and magnetic amplifier L1. The output from magnetic amplifier L1 is converted to d.c. firing pulses by diodes CR12, CR13, CR14, CR15, CR16, and CR17 and resistors R18, R19, R20, R21, R22, and R23 and is applied to SCR thyristors CR10 and CR11. Resistor R24 and capacitor C7 prevent snap-on action of magnetic amplifier L1. SCR thyristors CR10 and CR11, together with diodes CR7 and CR9, form a single-phase, full-wave control rectifier bridge


FROM TRANSISTORIZED DIFFERENTIAL AMPLIFER
L1
T3
TO SATURABLE TRANSFORMERS
CR17
SIGNAL
R24
CR13
R22
CR12
FILTER
CR16
R20
R18
CR10
CR7
CR8
R21
R19
C7
CR9
CR11
CR15
R23
CR14
C8
R26
OUTPUT
R28
R27

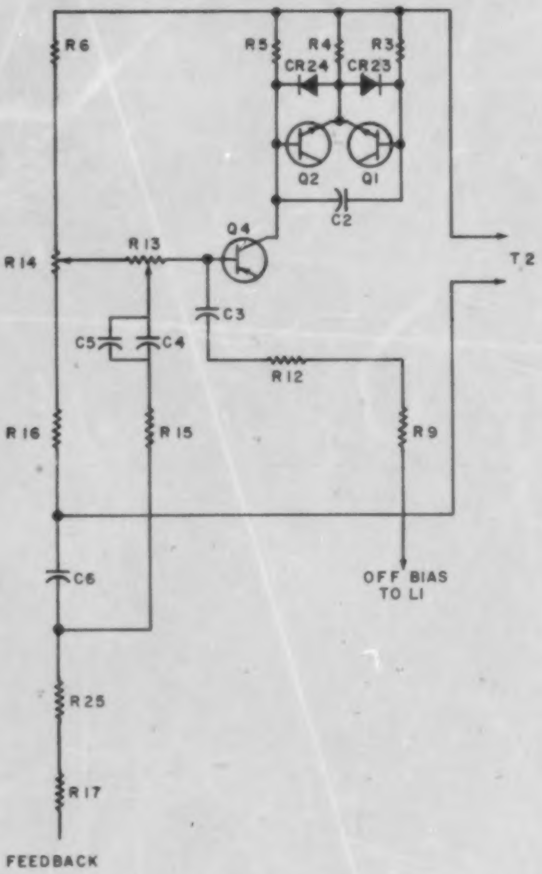
111.165

Figure 4-6.—Rectifier Circuit.

that supplies d.c. current to the control winding of the saturable transformer during automatic operation. As the output of L1 decreases, SCR thyristors CR10 and CR11 together with diodes CR7 and CR9 decreases; thus, causing the d.c. signal in the saturable transformer to decrease. This action causes the saturable core to have less impedance and its output will increase to reestablish terminal voltage. Adjustable resistors R27 and R28 are factory adjusted to limit the current to 4.5 amperes maximum. Diode CR8 is a flyback diode that provides a current path for the inductance current whenever the applied d.c. voltage is interrupted. Resistor R26 and capacitor C8 form a filter network across the control rectifier bridge.

Stabilizer Circuit (Figure 4-7)

An R-C feedback circuit, consisting of potentiometer R13, capacitors C4, C5, and C6, and resistors R15, R17, and R25, forms a stability control circuit. The stability signal is taken from the generator field and applied to the base of transistor Q4. The magnitude of the



111.166

Figure 4-7.—Stabilizer Circuit.

signal applied to the base of Q4 is determined by the setting of potentiometer R13. Resistor R12 and capacitor C3 form an R-C circuit that provides interloop stability. Diodes CR23 and CR24 limit the reverse emitter-to-base voltage. Capacitor C2 prevents high frequency oscillations.

You have now gone through the components of the voltage regulator. Referring to figure 4-8 you will see the interconnections of each circuit.

MANUAL OPERATION OF THE EXCITER-REGULATOR (Figure 4-9)

The manual voltage control provides a method of controlling the exciter output by manually controlling the d.c. current to the saturable transformer. The manual voltage control consists of the manual position of switch S60, variable resistor R70, and diodes CR18, CR19, CR20 and CR21. When S60 is in the manual position, the d.c. control current for the saturable transformer is supplied by the secondary of isolation transformer T4 (terminals 5 and 6), rectified by diodes CR18 through CR21, and manually controlled by variable resistor R70. The voltage regulator is energized but inoperative, and the generator voltage is subject to changes caused by variation in load, temperature, etc. Manual control allows operation that is independent of the voltage regulator.

FIELD FLASHING (Figure 4-10)

Field flashing is accomplished by a permanent magnet alternator (PMA), field flash switch, and diodes CR56, CR58, CR59, CR60, CR61, CR62 and CR63. When the prime mover is rotating, the attached PMA is producing an a.c. voltage. When the field flashing switch is closed, the a.c. voltage is applied to the diodes, thus applying a d.c. current directly to the generator field. Diode CR56 acts as a blocking diode to prevent the exciter from supplying current back into the PMA.

DROOP AND CROSS CURRENT COMPENSATION CIRCUIT (Figure 4-11)

During parallel operation, either a voltage droop circuit or cross-current circuit is necessary to provide reactive load division and to reduce circulating currents between generators in parallel. A current transformer (or transformers), located in the exciter section, and an adjustable resistor (R50) are required to obtain either droop or cross-current compensation.

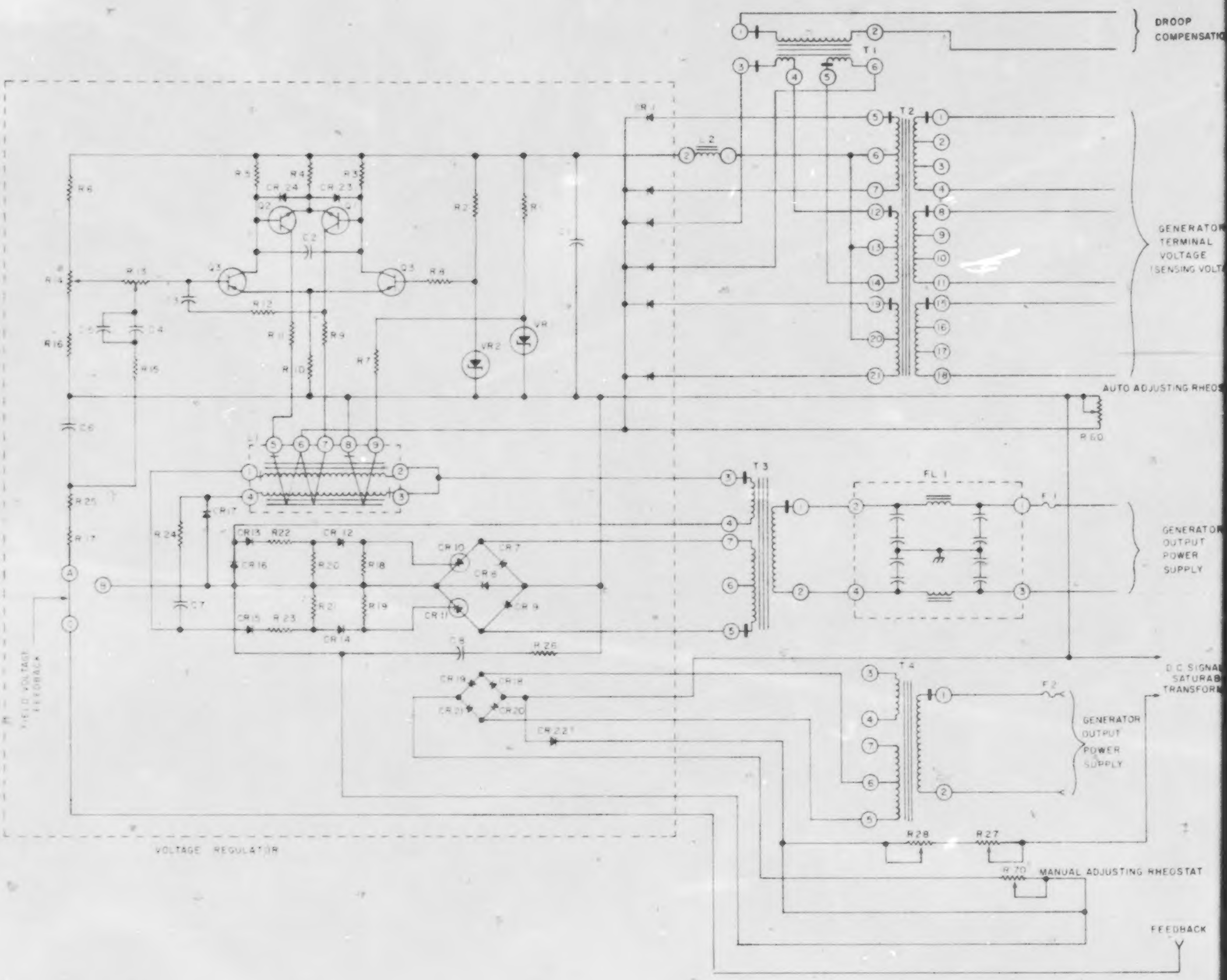

DROOP COMPENSATIO
T1
T2
L2
CR1
GENERATOR TERMINAL VOLTAGE (SENSING VOLT
AUTO ADJUSTING RHEOS
R60
R1
R2
R3
R4
R5
R6
R7
R8
R9
R10
R11
R12
R13
R14
R15
R16
R17
R24
R25
Q1
Q2
Q3
C1
C2
C3
C4
C5
C6
C7
C8
CR23
CR24
VR1
VR2
L1
T3
FL1
F1
GENERATOR OUTPUT POWER SUPPLY
CR13
R22
CR12
CR16
R20
R18
CR10
CR7
CR8
CR9
CR11
R21
R19
CR15
R23
CR14
CR17
R26
D.C. SIGNAL SATURAB TRANSFORM
T4
CR19
CR18
CR21
CR20
CR22
F2
GENERATOR OUTPUT POWER SUPPLY
R28
R27
R70
MANUAL ADJUSTING RHEOSTAT
FEEDBACK
FIELD VOLTAGE FEEDBACK
A
B
C
VOLTAGE REGULATOR

Figure 4-8.—Type SB-SR Voltage Regulator.

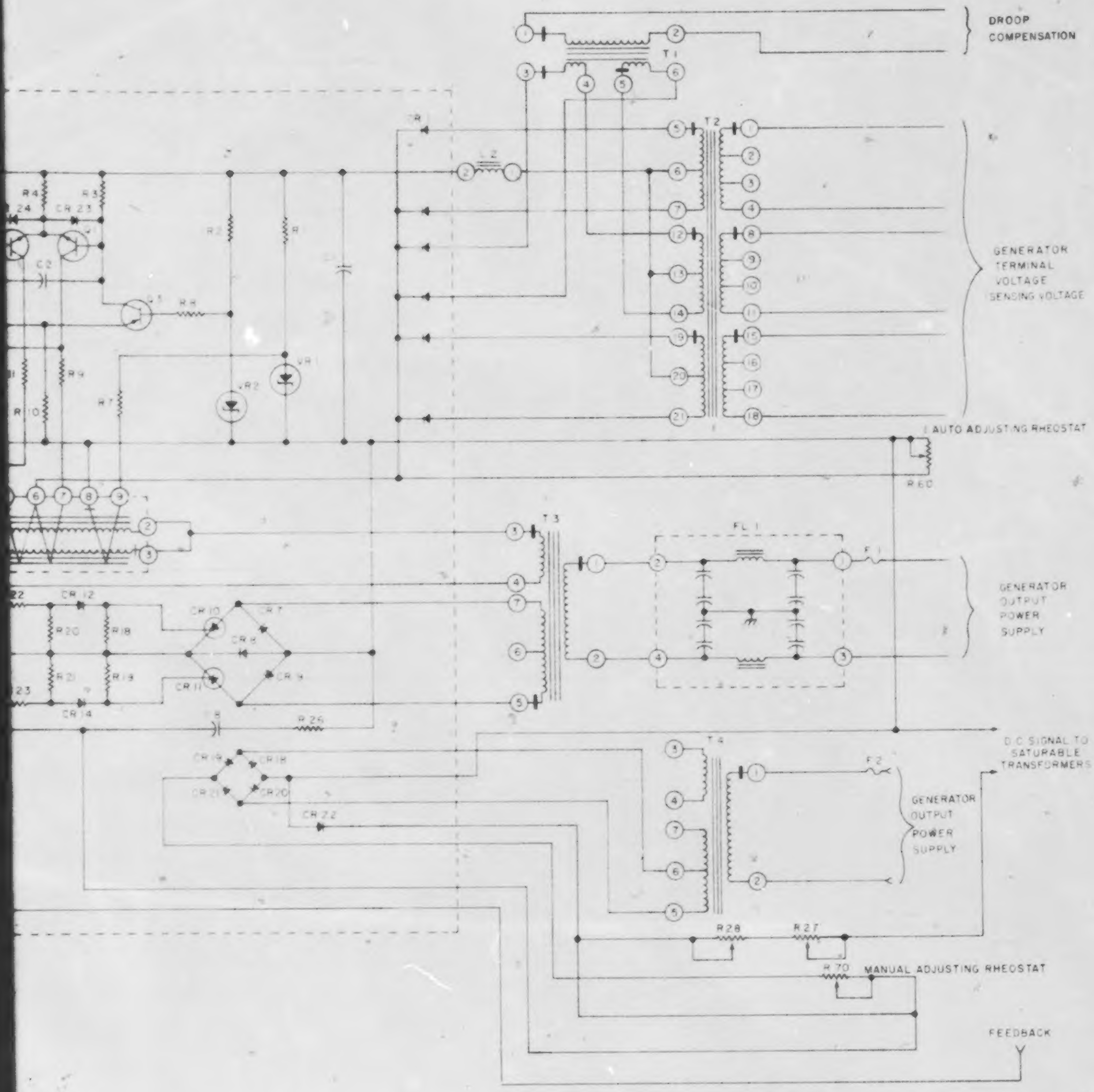
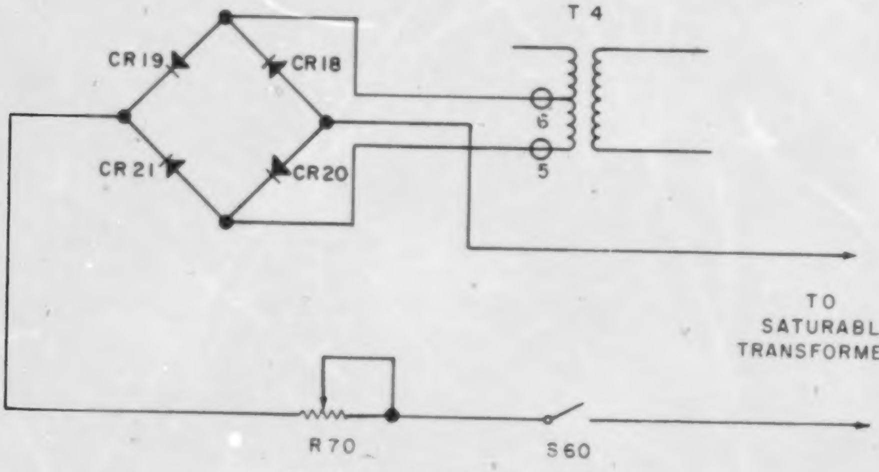
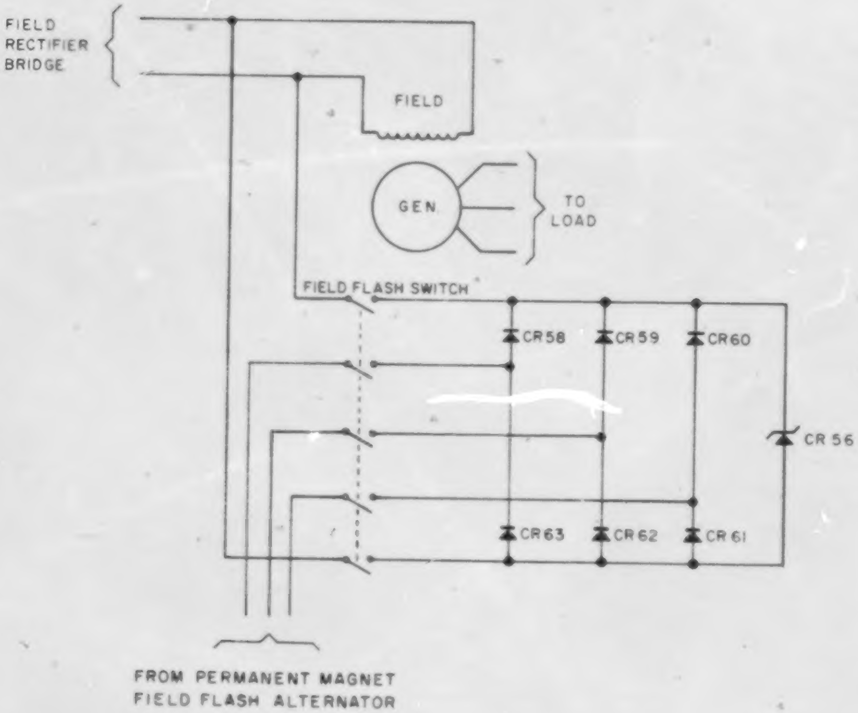

DROOP COMPENSATION
T1
T2
T3
T4
L2
CR1
GENERATOR TERMINAL VOLTAGE SENSING VOLTAGE
AUTO ADJUSTING RHEOSTAT
R60
FL1
F1
GENERATOR OUTPUT POWER SUPPLY
D.C. SIGNAL TO SATURABLE TRANSFORMERS
F2
GENERATOR OUTPUT POWER SUPPLY
R28
R27
R70
MANUAL ADJUSTING RHEOSTAT
FEEDBACK
R4
R3
CR24
CR23
Q1
C2
Q3
R8
R2
R1
VR1
VR2
R7
R9
R10
CR12
R20
R18
R21
R19
CR10
CR7
CR8
CR11
CR9
CR14
C8
R26
CR19
CR18
CR21
CR20
CR22

Figure 4-8.—Type SB-SR Voltage Regulator.


T 4
CR19
CR18
CR21
CR20
6
5
TO
SATURABLE
TRANSFORMERS
R70
S60

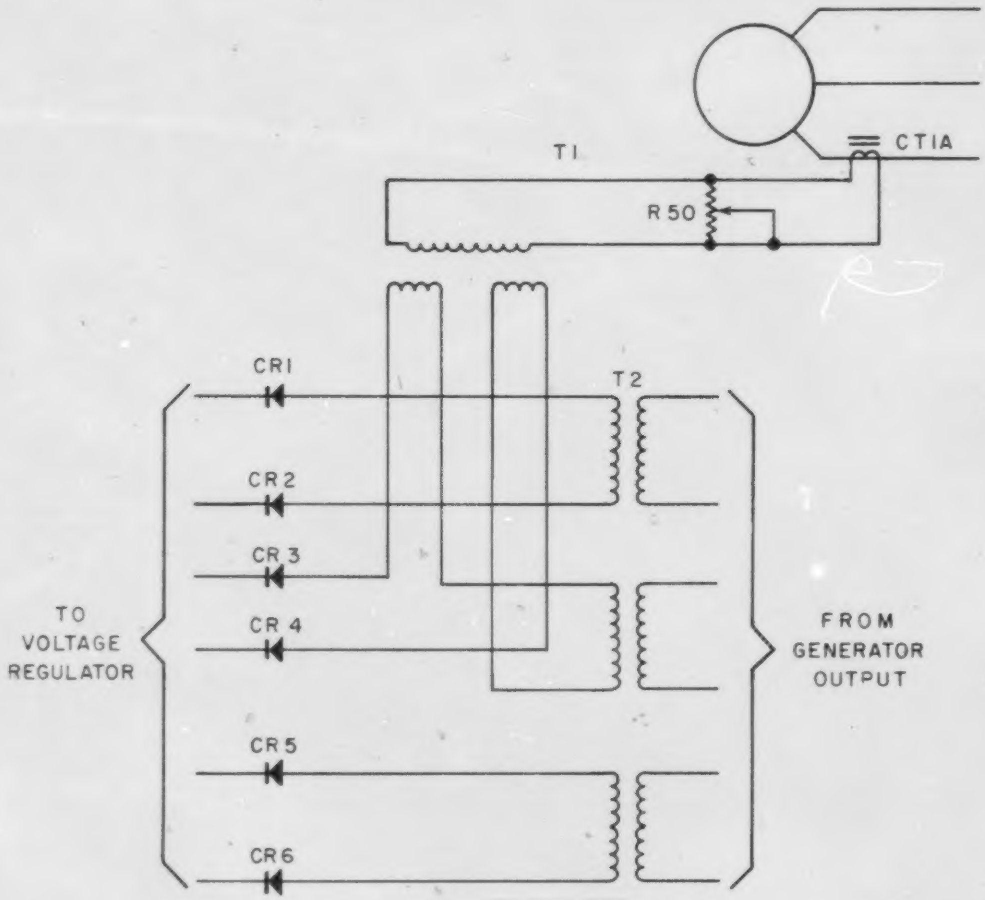
111.168

Figure 4-9.–Manual Voltage Control.


FIELD
RECTIFIER
BRIDGE
FIELD
GEN
TO
LOAD
FIELD FLASH SWITCH
CR58
CR59
CR60
CR56
CR63
CR62
CR61
FROM PERMANENT MAGNET
FIELD FLASH ALTERNATOR

111.169

Figure 4-10.–Field Flashing Circuit.



111.170

Figure 4-11.—Droop and Cross-current Compensation Circuit.

During parallel operation, a voltage that is 90° out of phase (for unity power factor) with the regulator input sensing voltage is developed across resistor R50. This voltage is proportional to the generator load current in magnitude and phase. The voltage applied to the sensing rectifiers (diodes CR1 through CR6) in the voltage regulator is the vectorial sum of the input sensing voltage from sensing transformer T2 plus the voltage developed across resistor R50, which is applied through parallel isolation transformer T1. When a resistive load is applied, the secondary voltage from T1 leads the sensing voltage from T2 by 90°. The vector sum of the two voltages is nearly the same as the original voltage from T2; consequently, no change occurs in the generator output voltage. When a lagging power factor (inductive) load is applied, the secondary voltage from T1 is in phase with the sensing voltage from T2, and the two voltages combine vectorially. Then, the resultant voltage applied to the sensing rectifier is large.

than before. Since the action of the regulator maintains a constant voltage at the sensing rectifiers, the regulator reacts by decreasing the generator output voltage. When a leading power factor (capacitive) load is applied, the secondary voltages combine vectorially in such a manner that the resultant voltage applied to the sensing rectifier is smaller than before. Then the regulator reacts by increasing the generator output voltage.

When two generators are in parallel during no load conditions and one supplies a lagging power factor (inductive) load, the load appears as a leading power factor (capacitive) load to the other generator. Then the reaction of the respective regulators is to decrease the output voltage of the first generator and increase the output voltage of the second generator. This action minimizes circulating currents between paralleled generators. Droop compensation allows paralleled generators to share reactive current loads proportionally by causing a decrease (droop) in the generator system output voltage.

MAINTENANCE

Since this system has no moving parts and, therefore, has inherent long life characteristics, little preventive maintenance is required other than that designated on the Maintenance Requirement Cards.

CAUTION

THE USE OF MEGGERS AND HIGH POTENTIAL TEST EQUIPMENT IS NOT RECOMMENDED. INCORRECT USE OF SUCH EQUIPMENT WILL DESTROY THE SEMICONDUCTORS IN THE EXCITER-REGULATOR.

SPR-400 LINE VOLTAGE REGULATOR

The SPR-400 line voltage regulator is a general purpose, automatically controlled a.c. line regulator designed for naval ships. It ensures precision voltage regulation for line, load, frequency, and power factor variations in single or three-phase (delta or wye connection) circuits. There are several designs of line voltage regulators available. The operation described in the next section will cover a typical design. The line voltage regulator is designed around the use of the silicon controlled rectifier, or SCR, which acts as a switch when a control voltage is applied to it.

OPERATION

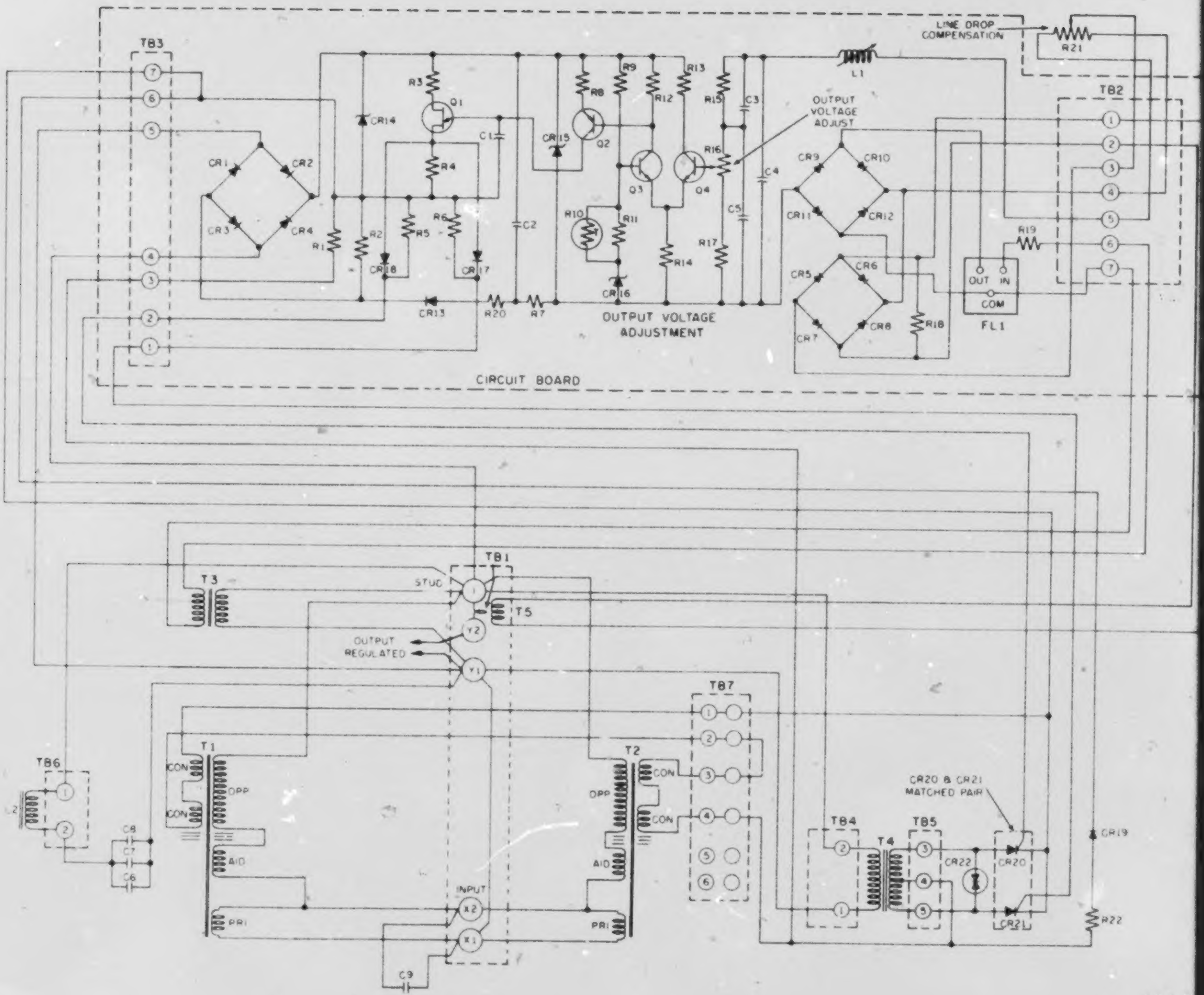
The voltage regulator is installed in series with the load which requires the precisely regulated power supply. The unit shown in figure 4-12 controls a single phase circuit. The input is at terminals X1 and X2 on terminal board 1 (TB1). Regulated output is from terminals Y1 and Y2 on TB1. Regulation is achieved by controlling the two auto transformers, T1 and T2. To ensure an acceptable wave form, one side of the transformer output goes to a harmonic filter via terminal 1 on TB1. The filter consists of the inductor L2 on TB6, and the parallel capacitors C6, C7, and C8.

Voltage from terminals Y1 and 1 on TB1 drives the rectifier bridge consisting of CR1, CR2, CR3, and CR4 on the circuit board. This bridge provides d.c. power for the solid state components on the board.

The input from the generator is sensed at X1 and X2. This signal is then applied to Y1 and 1 through autotransformers T1 and T2. Transformer T3 then sends this signal to differential amplifier Q3 and Q4 through rectifiers CR5 and CR12. Here the signal is compared to Zener diode (CR16) reference.

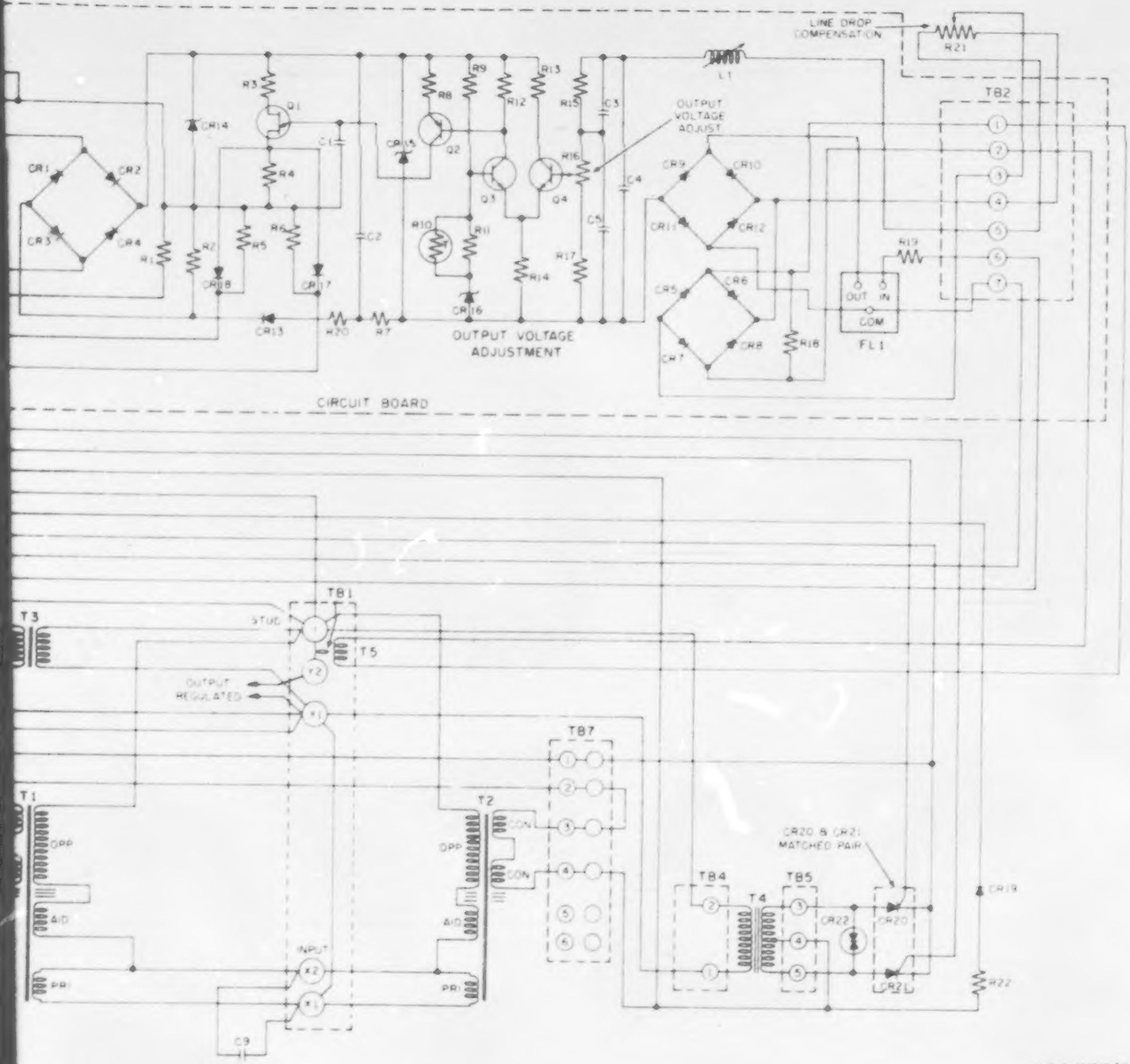
The pulse circuit Q1 responds to the error signal from the differential amplifier, which has been amplified by Q2. The pulses are transmitted to the silicon-controlled rectifiers (SCR's) CR20 and CR21 (via terminals 1 and 2 of TB3). The SCR's determine the level of d.c. to the control windings of T1 and T2 and thus regulate the output.

Remember, the application of input power (across terminals X1 and X2 of TB1, fig. 4-12)


LINE DROP COMPENSATION
R21
TB3
TB2
L1
R3
Q1
CR14
C1
R8
R9
R12
R13
R15
C3
CR15
Q2
OUTPUT VOLTAGE ADJUST
Q3
Q4
R16
C4
CR1
CR2
CR3
CR4
R4
R1
R2
R5
R6
C2
R10
R11
C5
R14
R17
CR9
CR10
CR11
CR12
CR5
CR6
CR7
CR8
R18
R19
OUT
IN
COM
FL1
CR18
CR17
CR16
CR13
R20
R7
OUTPUT VOLTAGE ADJUSTMENT
CIRCUIT BOARD
TB1
STUD
T3
T5
Y2
Y1
OUTPUT REGULATED
TB7
T1
T2
CON
OPP
AID
PRI
INPUT
X2
X1
C9
TB6
L2
C8
C7
C6
CR20 & CR21 MATCHED PAIR
TB4
T4
TB5
CR22
CR20
CR21
CR19
R22

111.1

Figure 4-12.—SPR-400 Line Voltage Regulator.


LINE DROP COMPENSATION
R21
L1
TB2
OUTPUT VOLTAGE ADJUST
R3
Q1
CR14
C1
R8
R9
R12
R13
R15
C3
CR15
Q2
Q3
Q4
R16
C4
CR1
CR2
CR3
CR4
R4
R1
R2
R5
R6
CR18
CR17
CR13
R20
R7
C2
R10
R11
R14
CR16
C5
R17
OUTPUT VOLTAGE ADJUSTMENT
CR9
CR10
CR11
CR12
CR5
CR6
CR7
CR8
R18
R19
OUT
IN
COM
FL1
CIRCUIT BOARD
TB1
T3
STUD
T5
OUTPUT REGULATED
X2
X1
TB7
T1
OPP
AID
PRI
INPUT
C9
T2
CON
TB4
T4
TB5
CR22
CR20 & CR21 MATCHED PAIR
CR20
CR21
CR19
R22

111.102(111C)

Figure 4-12.—SPR-400 Line Voltage Regulator.

energizes the two parallel operated autotransformers. The input voltage is stepped up by an aiding winding (AID) wound directly over the primary winding (PRI). The voltage is then reduced to nominal output by an opposing winding (OPP). The magnitude of induced voltage in the opposing winding is varied by the level of d.c. in the control windings (CON) from the SCR's. The opposing and the control windings are separated from the primary and the aiding windings by a magnetic shunt. Increasing the d.c. in the control windings forces the magnetic flux through the shunt, decreasing the opposing voltage, and thus increasing the output.

Power to the SCR'S is taken from stepdown transformer T4, whose primary is connected across the regulator output. Diode CR19 provides a discharge path via terminals 6 and 7 of TB3 for the control windings of T1 and T2 when the SCR's are shut off. The SCR's are protected from excessive peak inverse voltage by silicone diode CR22. The silicone diode acts as an insulator during normal operation, but when an excessive voltage is applied to it, it shorts and thus protects the SCR's. When the voltage returns to normal, the silicone diode will again be an insulator.

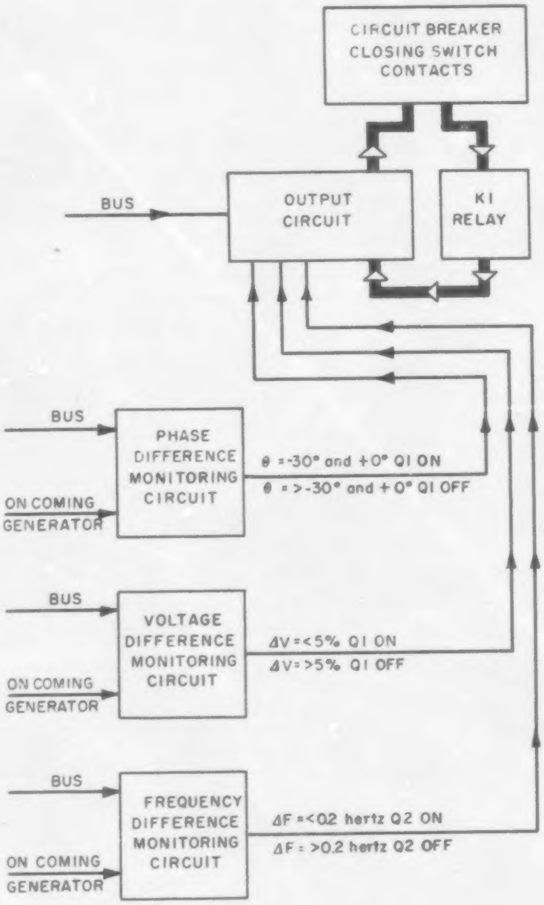
To provide an additional output voltage compensation for cable loss, the stud of terminal Y2 passes through current transformer T5 and induces a signal in T5 proportional to the load current. Adjustment of potentiometer R21 provides compensation in this circuit. The potentiometer setting compensates for the resistance in cables from the regulator to the load. Once set, it does not have to be changed unless the cables (not the load) are changed.

MAINTENANCE

Normally, little preventive maintenance, other than that described on the Maintenance Requirement Cards, is required because the components are stable and nonwearing with no moving parts (other than two potentiometers). Make frequent inspections for dust, dirt, and moisture accumulation and clean the equipment as necessary.

SYNCHRONIZING MONITOR

The synchronizing monitor (fig. 4-13) monitors the phase angle, voltage, and frequency relationship between a 450-volt, 60-hertz generator and an energized bus. Circuits within this panel energize a relay when the phase angle (Ø) is between -30° and 0°, the voltage difference (ΔV) is less than 5 percent, or the frequency drift (ΔF) between an oncoming generator and an energized bus is less than 0.2 hertz.


CIRCUIT BREAKER CLOSING SWITCH CONTACTS
BUS
OUTPUT CIRCUIT
K1 RELAY
BUS
PHASE DIFFERENCE MONITORING CIRCUIT
ON COMING GENERATOR
θ =-30° and +0° Q1 ON
θ = >-30° and +0° Q1 OFF
BUS
VOLTAGE DIFFERENCE MONITORING CIRCUIT
ON COMING GENERATOR
ΔV=<5% Q1 ON
ΔV=>5% Q1 OFF
BUS
FREQUENCY DIFFERENCE MONITORING CIRCUIT
ON COMING GENERATOR
ΔF =<0.2 hertz Q2 ON
ΔF = >0.2 hertz Q2 OFF

111.105

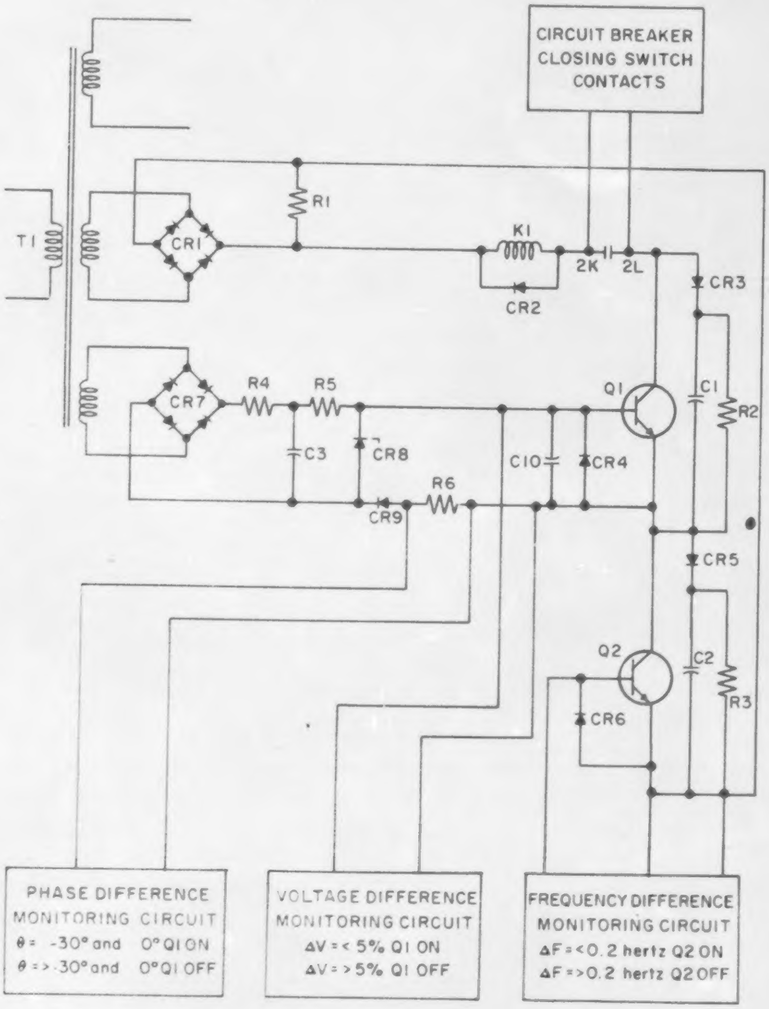
Figure 4-13.–Block Diagram of Synchronizing Monitor.

The synchronizing monitor does not automatically parallel two generators when it is connected to the system. The generators must be paralleled manually, whether or not the synchronizing monitor is connected to the circuit. The function of the synchronizing monitor is to prevent the manual paralleling of two generators when the phase angle, voltage difference, and frequency difference of the two generators are not within safe limits.

The synchronizing monitor consists of four main circuits: the output circuit, the phase difference monitor circuit, the voltage difference monitoring circuit, and the frequency difference monitoring circuit.

OUTPUT CIRCUIT

The output circuit (fig. 4-14) contains the K1 relay, its power supply, and a set of contacts


CIRCUIT BREAKER CLOSING SWITCH CONTACTS
T1
CR1
R1
K1
2K
2L
CR2
CR3
CR7
R4
R5
C3
CR8
R6
CR9
C10
CR4
Q1
C1
R2
CR5
Q2
C2
R3
CR6
PHASE DIFFERENCE MONITORING CIRCUIT
θ = -30° and 0° Q1 ON
θ => -30° and 0° Q1 OFF
VOLTAGE DIFFERENCE MONITORING CIRCUIT
ΔV = < 5% Q1 ON
ΔV = > 5% Q1 OFF
FREQUENCY DIFFERENCE MONITORING CIRCUIT
ΔF = < 0.2 hertz Q2 ON
ΔF = > 0.2 hertz Q2 OFF

111.106

Figure 4-14.—Output Circuit.

(circuit breaker closing switch contacts) in series with transistors Q1 and Q2. The K1 relay provides an electrical interlock through the closing circuit of a circuit breaker. This interlock will prevent an operator from electrically closing the circuit breaker unless the necessary conditions have been met. To energize the K1 relay, the circuit breaker closing contacts must be open and Q1 and Q2 must be ON. With proper "circuit breaker line up," the first condition is met. To turn on Q1 and Q2, the monitoring circuits must provide the current signals to Q1 and Q2.

Looking at the schematic in figure 4-15, you can see that the energized bus voltage is stepped down by secondary winding X1 and X2 of transformer T1, and rectified by full-wave rectifier CR1 to form the power supply for relay K1 and transistors Q1 and Q2. Full-wave rectifier CR7 rectifies the output of secondary winding X3 and X4 of transformer T1 to form the reference bias supply to transistor Q1. Resistor R4 and capacitor C3 filter the output of rectifier CR7. Zener diode CR8, due to its flat voltage characteristic, maintains a constant reference to Q1. Resistor R5 is a voltage dropping resistor that limits the voltage across Zener diode CR8 to a safe value. If the voltage applied to R5 and CR8 increases, the increased voltage is absorbed as an IR drop across R5, and the voltage across CR8 remains constant.

Two circuits affect the bias voltage of Q1. The first circuit is the phase difference monitoring circuit, which includes resistor R6. When a voltage of sufficient magnitude is developed across R6, the base to emitter bias of transistor Q1 is reversed, turning off Q1. The second circuit is the voltage difference monitoring circuit connected across the base to emitter of transistor Q1. When transistor Q5 conducts, this circuit disables Q1 by shorting the base to emitter of Q1, thus removing the bias reference supply. Q1 can conduct or be biased on only when these two circuits are off. The action by the Q1 transistor is similar to that of a switch. A transistor can be used so that it acts like contacts that are either closed or opened. This is done by using a large enough base current signal, so that it can drive the transistor into saturation. This, in turn, acts like a short circuit (equivalent to closed contacts). If the base current signal is weakened, reversed, or eliminated, the transistor then acts as an open circuit (equivalent to open contacts).

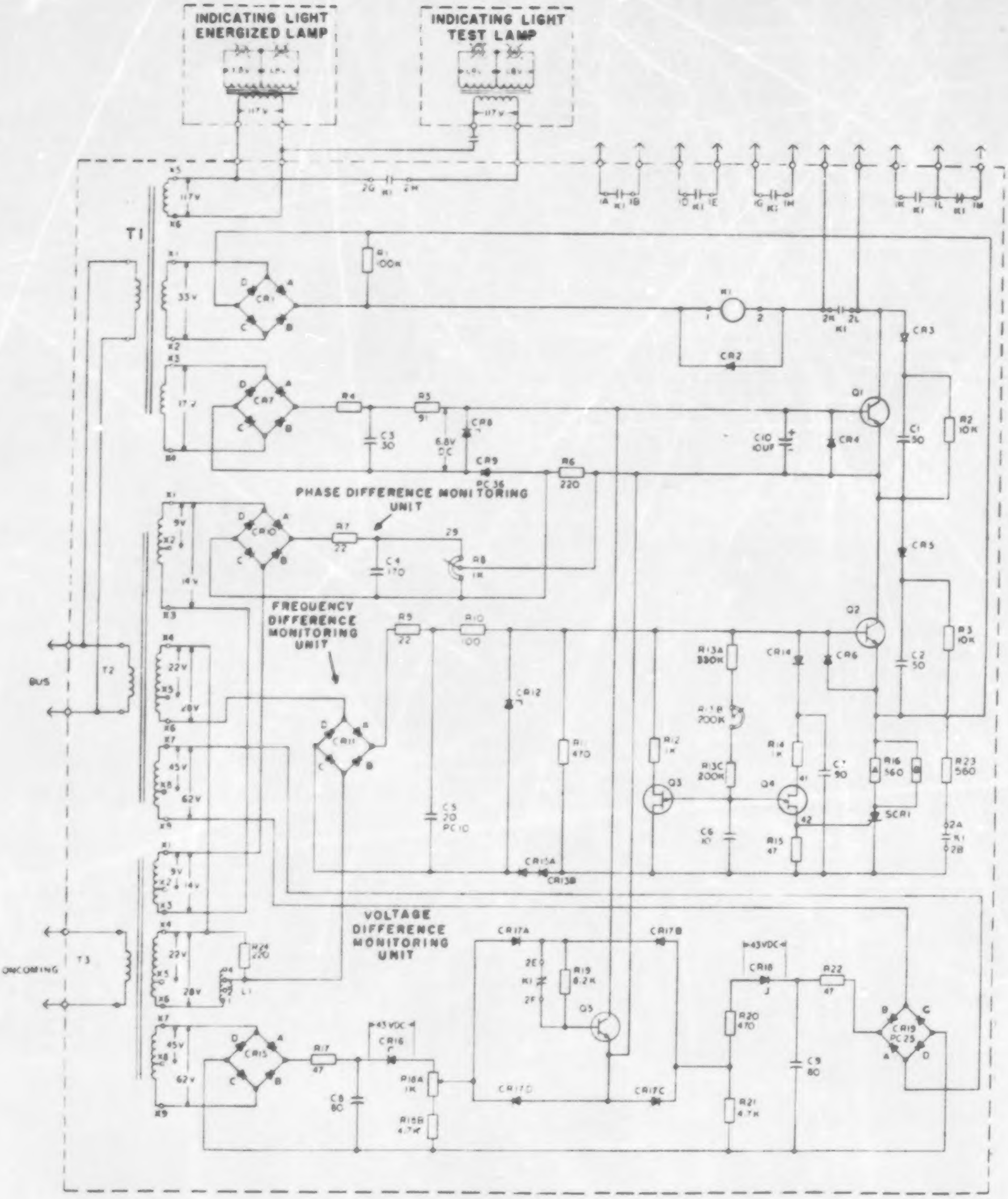
Transistor Q2 completes the circuit to energize relay K1. Transistor Q2 is biased on from the frequency difference monitor. Rectifiers CR2, CR3, and CR5, capacitors C1 and C2, and resistors R2 and R3 damp-out voltage spikes on Q1 and Q2. Rectifiers CR4 and CR6 limit emitter to base (reverse bias) voltages on Q1 and Q2 to low values.

To sum up the operation of this circuit: relay K1 is energized when transistors Q1 and Q2 are biased on, and circuit breaker switch contacts connected between 2K and 2L are closed.

PHASE DIFFERENCE MONITORING CIRCUIT

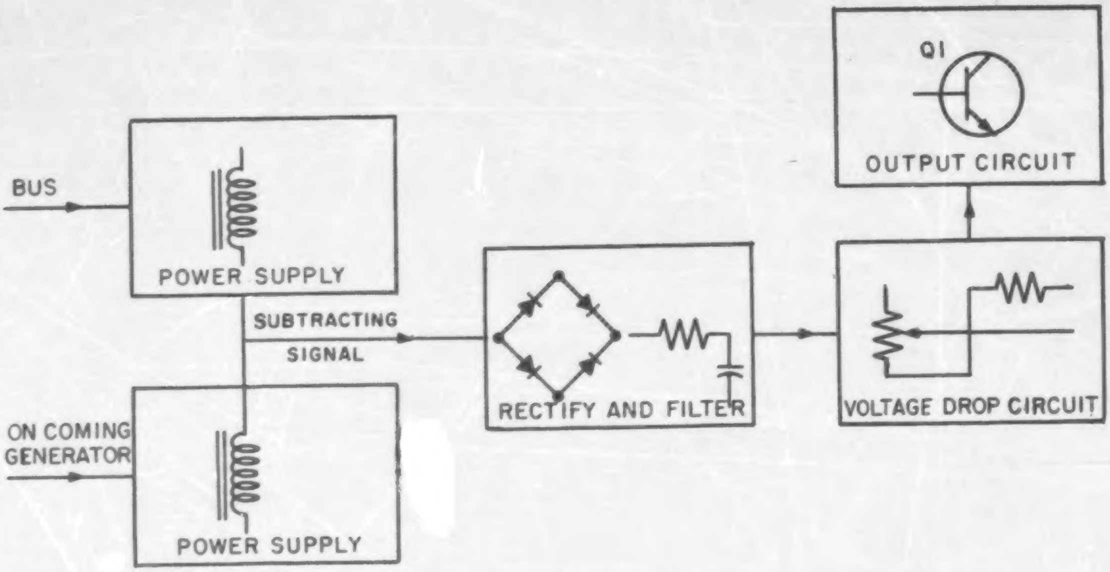
The phase difference monitoring circuit (fig. 4-16) prevents energizing of the K1 relay if the phase difference between the bus and the oncoming generator is more than -30° and 0°. It does this by reducing and comparing both input voltages (bus and incoming generator); rectifying and filtering both input voltages; and using its output to control transistor Q1.

Looking at the schematic in figure 4-17, the secondary winding X1 and X3 of T2 and X1 and X3 of T3 are connected so that the output voltages of T2 and T3 subtract from each other. For instance, assume that the voltages are in phase as shown in figure 4-18. When these voltages are in phase, the potential at points A and B (across rectifier CR10) in figure 4-18 will be the same, so no current can flow. Now assume that the energized bus and the oncoming generator are 180° out of phase, as shown in figure 4-19. Under these conditions the voltage at point A is at a maximum in a positive direction, while the voltage at point B is at a maximum in a negative direction. This causes maximum current to flow in rectifier CR10. Filtering of the rectified current is accomplished


INDICATING LIGHT ENERGIZED LAMP
18V
18V
117V
INDICATING LIGHT TEST LAMP
18V
18V
117V
2G
K1
2H
1A
K1
1B
1D
K1
1E
1G
K1
1H
1K
K1
1L
K1
1M
T1
X5
117V
X6
X1
R1
100K
33V
CR1
D
A
C
B
X2
X3
17V
CR7
R4
R5
91
C3
30
6.8V
DC
CR8
CR9
PC 36
R6
220
X4
K1
1
2
2K
2L
K1
CR2
CR3
Q1
C10
10UF
CR4
C1
50
R2
10K
PHASE DIFFERENCE MONITORING UNIT
9V
X2
14V
CR10
R7
22
C4
170
29
R8
1K
CR5
X3
FREQUENCY DIFFERENCE MONITORING UNIT
R9
22
R10
100
Q2
R13A
330K
CR14
CR6
R3
10K
C2
50
BUS
T2
X4
22V
X5
28V
X6
CR12
CR11
R13B
200K
X7
45V
X8
62V
X9
C5
20
PC10
R11
470
R12
1K
Q3
R13C
200K
R14
1K
Q4
41
C7
90
R16
560
R23
560
SCR1
42
C6
10
R15
47
2A
K1
2B
CR13A
CR13B
X1
9V
X2
14V
X3
VOLTAGE DIFFERENCE MONITORING UNIT
CR17A
CR17B
ONCOMING
T3
X4
22V
X5
28V
X6
R24
220
L1
2E
K1
2F
R19
8.2K
Q5
43VDC
CR18
J
R22
47
X7
45V
X8
62V
X9
CR15
R17
47
43VDC
CR16
R18A
1K
R18B
4.7K
C8
80
CR17D
CR17C
R20
470
R21
4.7K
C9
80
CR19
PC25
B
C
A
D

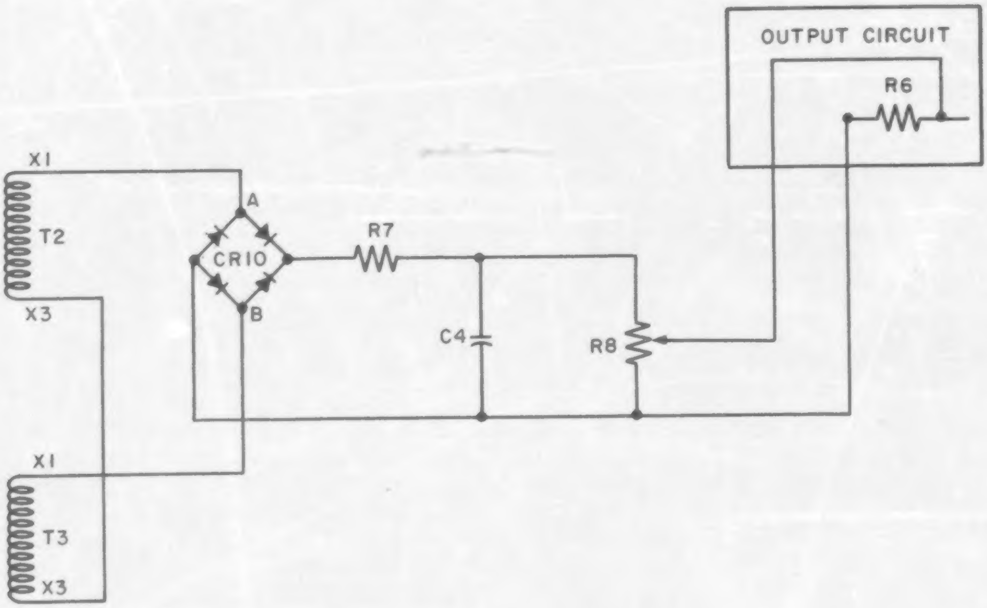
111.107

Figure 4-15.—Synchronizing Monitor.


Q1
OUTPUT CIRCUIT
BUS
POWER SUPPLY
SUBTRACTING
SIGNAL
RECTIFY AND FILTER
VOLTAGE DROP CIRCUIT
ON COMING
GENERATOR
POWER SUPPLY

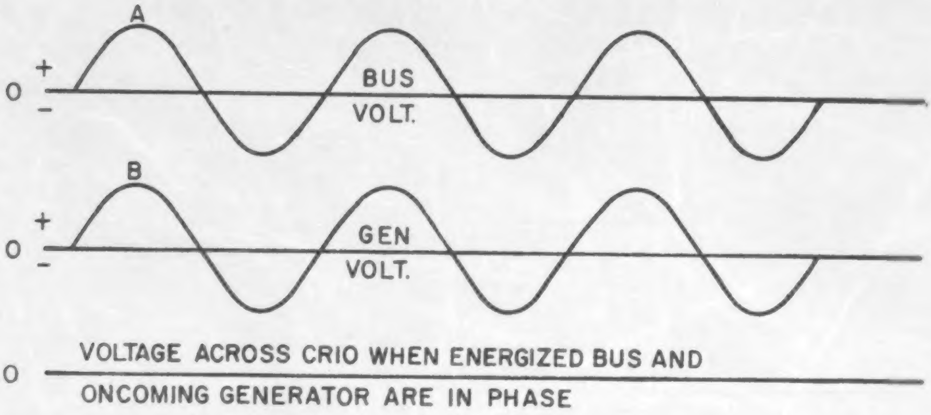
111.108

Figure 4-16.–Block Diagram of Phase Difference Monitoring Circuit.


OUTPUT CIRCUIT
R6
X1
T2
X3
A
CR10
B
R7
C4
R8
X1
T3
X3

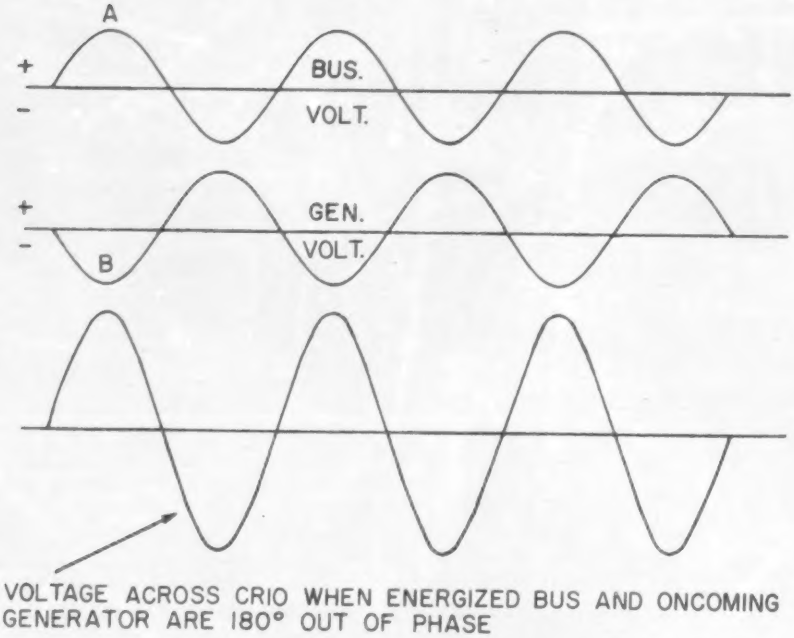
111.109

Figure 4-17.–Schematic Diagram of Phase Difference Monitoring Circuit.


A
+
0
-
BUS
VOLT.
B
+
0
-
GEN
VOLT.
0
VOLTAGE ACROSS CRIO WHEN ENERGIZED BUS AND
ONCOMING GENERATOR ARE IN PHASE

111.110

Figure 4-18.—Input Voltage to CR10 (in phase).


A
+
-
BUS.
VOLT.
+
-
B
GEN.
VOLT.
VOLTAGE ACROSS CRIO WHEN ENERGIZED BUS AND ONCOMING
GENERATOR ARE 180° OUT OF PHASE

111.111

Figure 4-19.—Input Voltage to CR10 (180° out of phase).

by resistor R7 and capacitor C4 (fig. 4-17). Remember that when no phase difference exists between the energized bus and the oncoming generator, the CR10 rectifier output is zero, and that a maximum output is developed when the difference is 180° between the two signals. The CR10 output is applied across resistors R8 and R6. At a given magnitude, the voltage drop across resistor R6 (fig. 4-15) overcomes the positive bias from base to emitter of transistor

Q1 (due to Zener diode CR8), and the net result is a negative bias which shuts off transistor Q1.

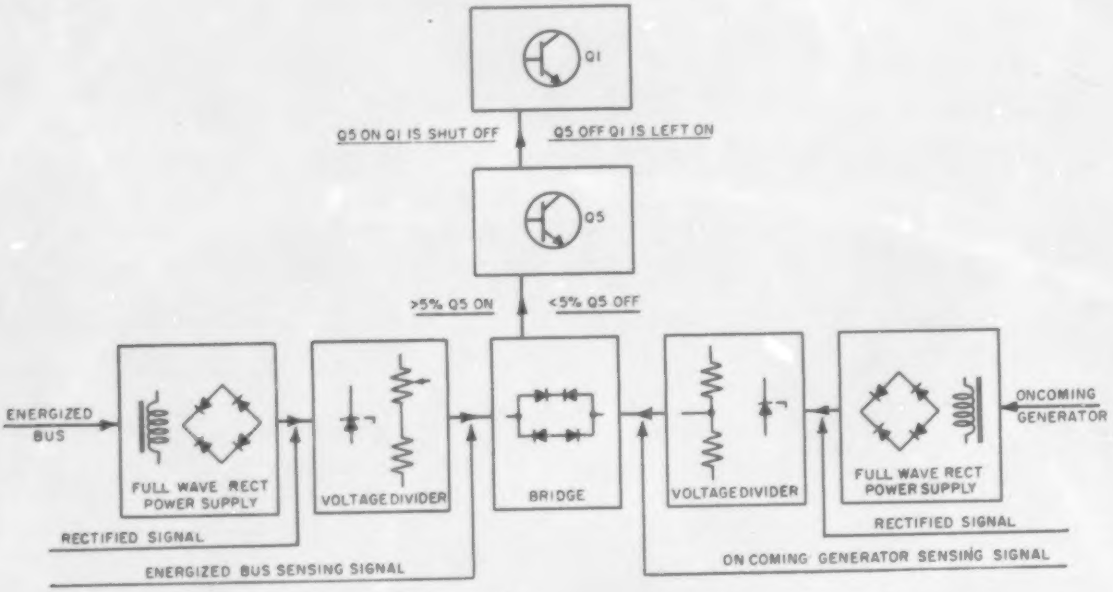
VOLTAGE DIFFERENCE MONITORING CIRCUIT

The voltage difference monitoring circuit prevents energizing of the K1 relay if the voltage difference between the bus and the oncoming generator is more than 5 percent. It does this by (fig. 4-20) reducing and rectifying both input voltages (bus and incoming generator); producing and delivering a sensing signal from each input; comparing the difference in magnitude of the two sensing signals in a bridge circuit; and using transistor Q5 for an ON-OFF switch.

Looking at the schematic in figure 4-21, you can see that the bus voltage is stepped down by winding X7 and X9 on T2. The reduced voltage is then rectified by full-wave rectifier CR19 and filtered by R22 and C9. The same thing occurs for the oncoming generator voltage at T3. Transformer T3 steps the voltage down, CR15 rectifies it, and R17 and C8 filters it.

Zener diode CR18 is used to increase the sensitivity of voltage divider R20 and R21 in the bus signal circuit. The Zener diode causes all the increase or decrease of the bus signal voltage to appear across the voltage divider. This also happens to voltage divider R18A and R18B, using Zener diode CR16. The resultant signal out of each voltage divider is the sensing signal. These sensing signals are then fed to a rectifier bridge consisting of CR's 17A, B, C, and D. When the bus and the oncoming generator sensing signals are equal, there is zero voltage between the bridge (points A and B). A difference between the bus voltage and the oncoming voltage causes a voltage to exist across the bridge.

Connected between points A and B of the bridge is the emitter and base of transistor Q5. The collector of Q5 is connected to the base of Q1, and the circuit is completed from the emitter of Q1 to the emitter of Q5. If the


Q1
Q5 ON Q1 IS SHUT OFF
Q5 OFF Q1 IS LEFT ON
Q5
>5% Q5 ON
<5% Q5 OFF
ENERGIZED BUS
FULL WAVE RECT POWER SUPPLY
VOLTAGE DIVIDER
BRIDGE
VOLTAGE DIVIDER
FULL WAVE RECT POWER SUPPLY
ONCOMING GENERATOR
RECTIFIED SIGNAL
ENERGIZED BUS SENSING SIGNAL
RECTIFIED SIGNAL
ON COMING GENERATOR SENSING SIGNAL

111.112

Figure 4-20.—Block Diagram of Voltage Difference Monitoring Circuit.

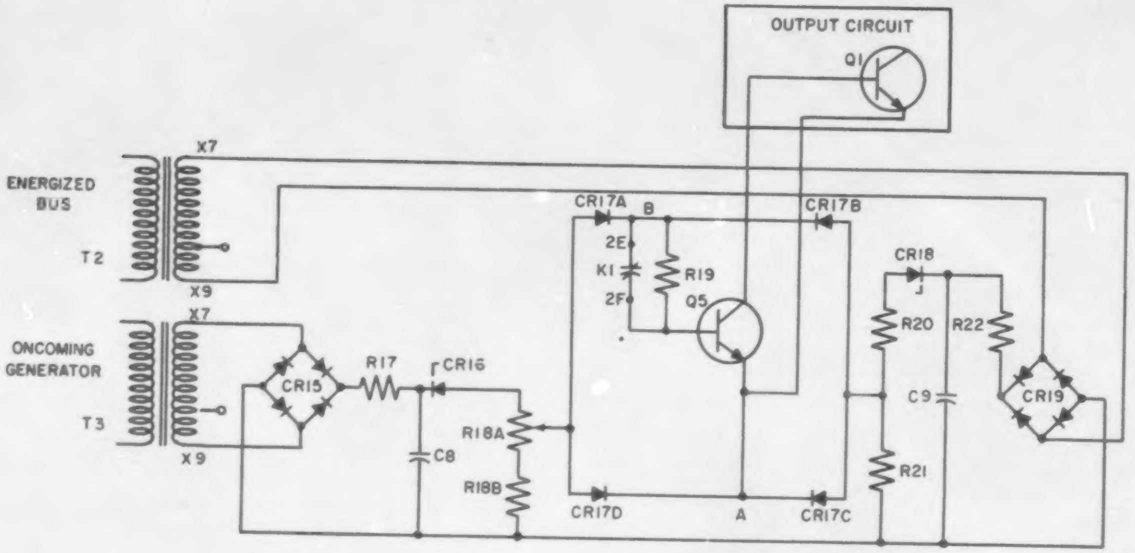


Figure 4-21.—Schematic Diagram of Voltage Difference Monitoring Circuit.

111.113

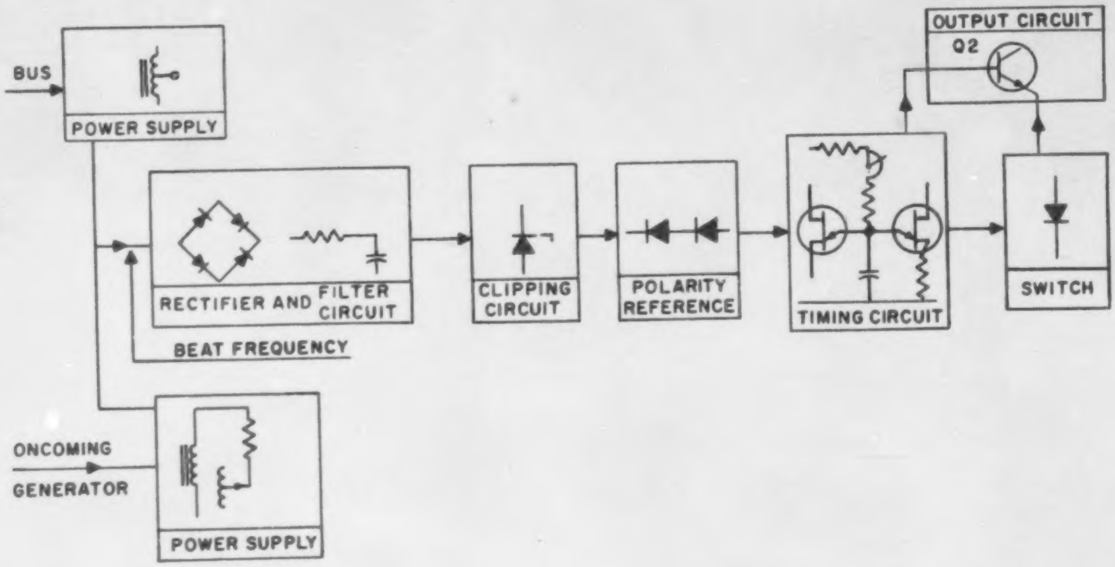
voltage between A and B (across the bridge) is zero, Q5 cannot be biased on, and therefore the base to emitter of Q1 is not shorted out. If a voltage does appear across points A and B of the bridge, which can be caused by as little as a 5 percent voltage difference between the bus and the oncoming generator, Q5 will be biased on and short out the base to emitter of Q1. This will turn off Q1 (fig. 4-15) and prevent energizing of relay K1. Resistor R19 prevents small momentary changes in voltage differences from turning on Q5 once relay K1 has picked up.

FREQUENCY DIFFERENCE MONITORING CIRCUIT

This circuit prevents energizing of relay K1 if the frequency difference between the bus and the oncoming generator is more than 0.2 hertz. It does this by (fig. 4-22) changing both frequency signals into a beat frequency voltage; rectifying, filtering, and reducing the beat frequency voltage; and then using the beat frequency voltage in a timing circuit to fire an SCR.

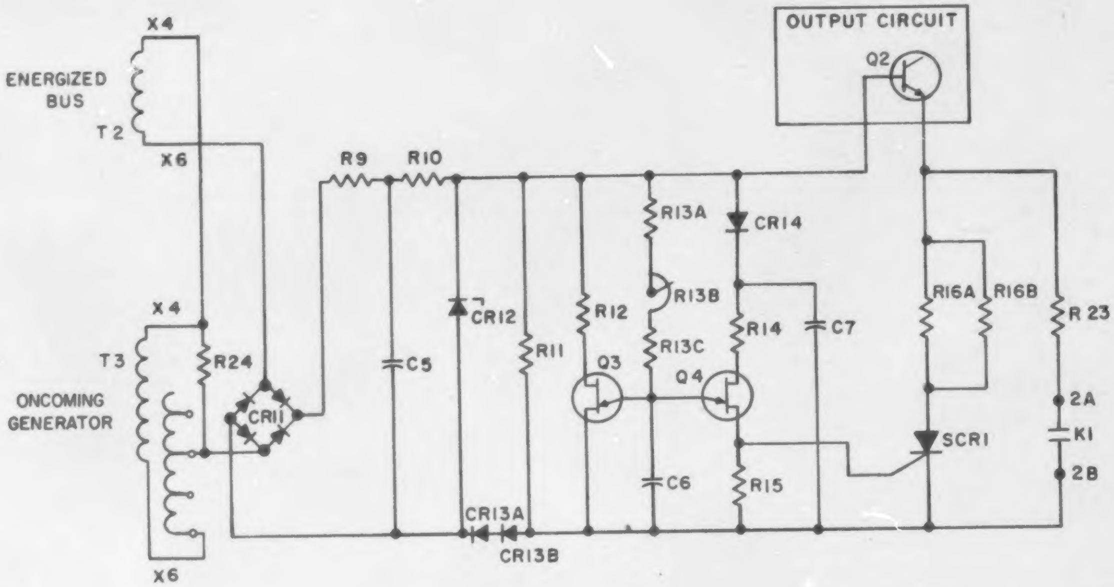
Look at the schematic in figure 4-23. The secondary winding X4 and X6 of T2 and X4 and X6 of T3 are connected in such a manner that a beat frequency voltage (heterodyne wave) is generated. This beat frequency voltage is the difference between bus and the oncoming generator frequencies (fig. 4-24A).

The beat frequency voltage is rectified by CR11 (fig. 4-23) and the resultant d.c. signal (fig. 4-24B) is filtered by resistor R9 and capacitor C5 (fig. 4-24C). The beat frequency voltage is clipped by resistor R10 and Zener diode CR12 to a constant d.c. level (fig. 4-24D). The signal is now sent to resistor R11 and diode CR13 (A and B), where about 1 volt is subtracted from the clipped beat frequency signal (fig. 4-24E). This is done to ensure that the clipped beat frequency voltage signal goes to zero when the original beat frequency goes to zero. At this point, the signal is a rectified, filtered, and clipped beat frequency voltage signal (heterodyne wave). The final step is to


OUTPUT CIRCUIT
Q2
BUS
POWER SUPPLY
RECTIFIER AND FILTER CIRCUIT
CLIPPING CIRCUIT
POLARITY REFERENCE
TIMING CIRCUIT
SWITCH
BEAT FREQUENCY
ONCOMING
GENERATOR
POWER SUPPLY

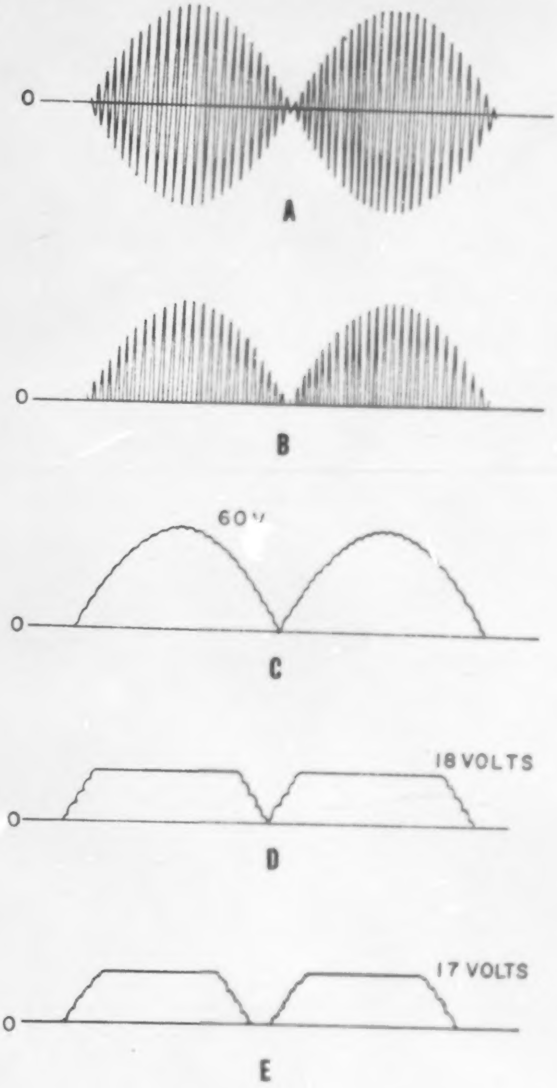
111.114

Figure 4-22.–Block Diagram of Frequency Difference Monitoring Circuit.


OUTPUT CIRCUIT
Q2
X4
ENERGIZED
BUS
T2
X6
R9
R10
R13A
CR14
R13B
X4
CR12
R12
R14
C7
R16A
R16B
R 23
T3
R24
C5
R11
Q3
R13C
Q4
ONCOMING
GENERATOR
CR11
2A
SCR1
K1
C6
R15
2B
CR13A
CR13B
X6

111.115

Figure 4-23.–Schematic Diagram of Frequency Difference Monitoring Circuit.



111.116
Figure 4-24.—Beat Frequency Voltages.

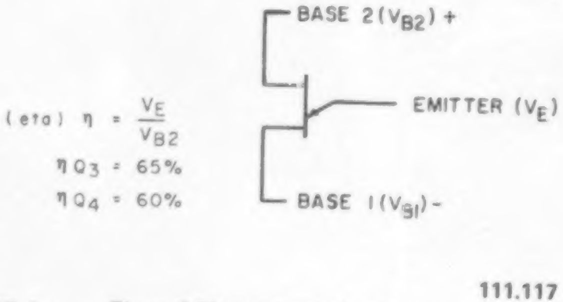
take this signal and feed it to the unijunction timing circuit. The clipped beat frequency voltage signal is applied across base 1 and base 2 of unijunction transistors Q3 and Q4 (Fig. 4-23), and also to the RC circuit consisting of resistors R13A, R13B, R13C, and capacitor C6.

Before continuing with the circuit description, you need a brief explanation of the operation of a unijunction transistor. A unijunction transistor has two bases, B1 and B2 and one emitter (fig. 4-25). The characteristics of a unijunction transistor are such that when the voltage between B1 and the emitter rises to a certain percentage of the voltage between B1 and B2, the unijunction transistor will fire. The percentage is equal to emitter voltage divided by the B2 voltage. In the case of the unijunction transistors, it is equal to a nominal 62 percent. This means that when the emitter voltage is approximately 60 percent of B2 voltage, both in reference to B1, the unijunction transistor will fire. By understanding that Q3 and Q4 have different values for the same voltage; that C6 has a definite charging rate (determined by R9, R10, R13, and rectifier CR14); and that different beat frequencies have different time intervals (and by using the following examples), you should have a basic understanding of how the timing circuit operates.

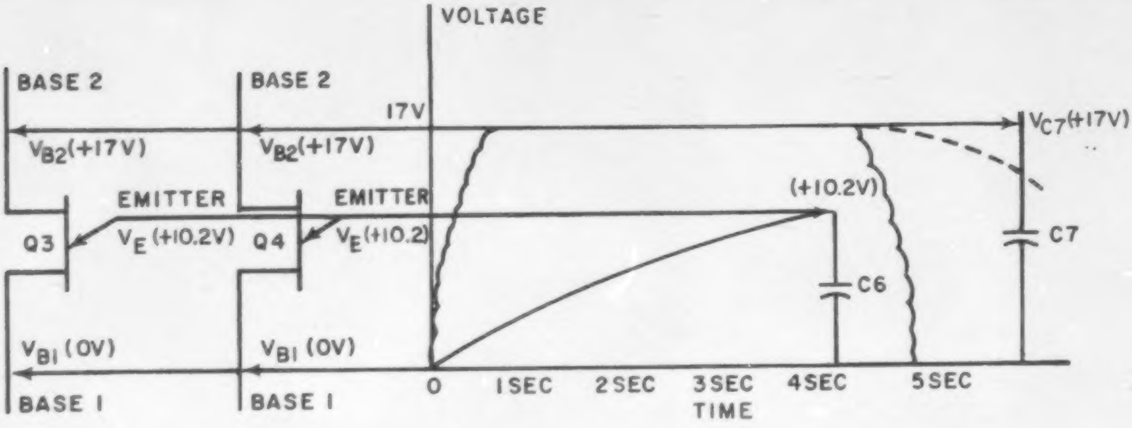
For the following examples, the values used are arbitrary. Let us use two examples to show how these unijunction transistors can be fired. In the first example (fig. 4-26), the beat frequency voltage is a difference of 0.2 hertz which causes a time period of 5 seconds for one cycle. Within the 5-second time period, the following events occur:

The voltage across Q3 and Q4 increases sharply and remains at 17 volts until the end of the cycle.

The 17 volts are applied across B1 and B2 of unijunction transistors Q3 and Q4, across capacitor C7, and across the RC circuit containing C6.



111.117
Figure 4-25.—Unijunction Transistor.


VOLTAGE
BASE 2
BASE 2
17V
V_{B2}(+17V)
V_{B2}(+17V)
V_{C7}(+17V)
EMITTER
EMITTER
(+10.2V)
Q3
V_E(+10.2V)
Q4
V_E(+10.2)
C7
C6
V_{B1}(OV)
V_{B1}(OV)
BASE 1
BASE 1
0
1 SEC
2 SEC
3 SEC
4 SEC
5 SEC
TIME

111.118

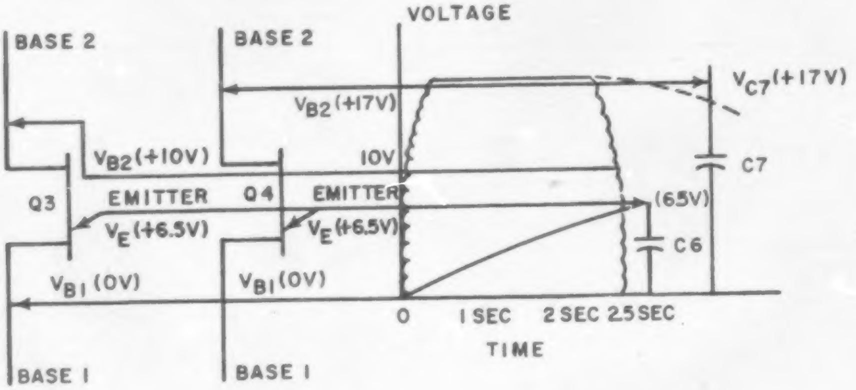
Figure 4-26.—Firing Sequence for Q4.

Capacitor C7 blocks rectifier CR14 and therefore will maintain approximately 17 volts. The only place C7 can discharge is through Q4, which has a very low leakage rate.

The RC circuit containing C6 is charging at a specific rate. If we assume that within 4 seconds C6 reaches 10.2 volts, then the following will occur:

The V_E for Q4 will fire before Q3. When Q4 fires, a voltage pulse is generated across R15 (fig. 4-23) and is applied to the gate of SCR1, which is then turned on. When SCR1 turns on transistor Q2 in the output circuit is supplied with a base current through limiting resistor R16 which turns on Q2. When the beat frequency voltage goes to zero, SCR1 turns off, and the timing process repeats itself.

In the second example (fig. 4-27), the beat frequency voltage is a difference of 0.4 hertz which causes a time period of 2.5 seconds for


VOLTAGE
BASE 2
BASE 2
V_{B2}(+17V)
V_{C7}(+17V)
V_{B2}(+10V)
10V
C7
Q3
EMITTER
Q4
EMITTER
(6.5V)
V_E(+6.5V)
V_E(+6.5V)
C6
V_{B1}(OV)
V_{B1}(OV)
0
1 SEC
2 SEC
2.5 SEC
TIME
BASE 1
BASE 1

111.119

Figure 4-27.—Firing Sequence for Q3.

one cycle. Within this 2.5-second time period, the following events occur:

The voltage across Q3 and Q4 increases sharply and remains at 17 volts until the end of the cycle.

The 17 volts are applied across B1 and B2 of unijunction transistors Q3 and Q4, across capacitor C7, and across the RC circuit containing C6.

Capacitor C6 charges at the same rate as before (assuming 10.2 volts in 4 seconds). The period of time for this cycle is only 2.5 seconds, therefore, the voltage across C6 can only reach approximately 6.5 volts within this time.

At the end of 2.5 seconds, approximately 17 volts are held across Q4 by capacitor C7, with a sharp decrease of voltage across B1 and B2 of Q3. When the voltage reaches approximately 10 volts, Q3 can fire due to its relative value of this voltage, whereas, Q4 still has approximately 17 volts across it.

After Q3 fires and the beat frequency goes to zero, the timing process again repeats itself.

You can see that different beat frequencies are compared just as the differences were in phase and voltage, and the function of the frequency difference circuit is to energize relay K1 through the control of transistor Q2, if the difference of the frequency of the bus and the oncoming generator is less than 0.2 hertz.

SERVICING TECHNIQUES FOR TRANSISTORIZED CIRCUITS

There are many differences between transistorized and electron tube circuits from the standpoint of servicing. For instance, you rely on your senses of sight, touch, and smell in the visual inspection of electron tube circuits. But this is not as feasible in transistor circuits. Many transistors develop so little heat that you can learn nothing by feeling them. High frequency transistors hardly get warm. Usually, if a transistor (except a high-power transistor) is hot enough to be noticeable, it has been damaged beyond use.

In electron tube circuits, you often make a quick test by the tube substitution method; that is, you replace the tube you suspect of being bad with one you know to be good. In transistorized circuits, the transistors are frequently soldered in and the substitution method is impractical. Furthermore, you should avoid indiscriminate substitution of transistors and other semiconductors. You should test transistors with an approved transistor test set.

TESTING

Most good quality test equipment used for electron tube testing can also be used for transistor circuit testing. You can use signal generators, both RF and AF, if the power supply in the equipment is isolated from the power line by a transformer. CAUTION: Before you make any tests with a signal generator, connect a common ground wire from the chassis of the equipment to be tested to the chassis of the signal generator before you make any other connections.

You can use signal tracers (such as dual trace oscilloscopes) on transistor circuits if you observe the precautions concerning the power supplies. Many signal tracers use transformerless power supplies; therefore, to prevent damage to the transistor, use an isolation transformer.

Multimeters used for voltage measurements in transistor circuits should have a high ohms/volt sensitivity (at least 20,000 ohms/volt) to ensure an accurate reading.

Ohmmeter circuits which pass a current of more than 1 milliampere through the circuit under test cannot be used safely in testing transistor circuits. Before using an ohmmeter on a transistor circuit, check how much current it passes on all range settings. Do not use any range for testing that passes more than 1 milliampere.

Conventional test prods, when used in the closely confined areas of transistor circuits, often are the cause of accidental shorts between adjacent terminals. In electron tube circuits the momentary short caused by test prods rarely results in damage, but in transistor circuits this short can destroy a transistor. Also, since transistors are very sensitive to improper bias voltages, you must avoid the practice of troubleshooting by shorting various points to ground and listening for a click. When you test transistor circuits, remember the vulnerability of a transistor to surge currents.

PRECAUTIONS

The following precautions should be observed when you service transistorized circuits.

Ensure that all power has been removed from the equipment under test before connecting any test equipment.

Connect a common ground lead from the chassis of the set under test to the test equipment before making any other connections.

Use an isolation transformer with all test equipment unless the test equipment has a transformer in its power supply.

Before using an ohmmeter to check resistance in a transistor circuit, ensure that the meter will not apply excessive voltage or voltage of the wrong polarity to the circuit. Do not use a range that passes more than 1 mA.

When unidentified transistors are encountered in equipment, you must identify their type before any testing is started. PNP and NPN transistors are not interchangeable.

When testing transistor circuits, do not remove a transistor while the power is on because you may damage the transistor or circuit under test.

Do not ground transistor elements while the power is on.

When soldering or unsoldering, use a light-duty soldering iron rated at 50 watts or less. If there is any doubt concerning leakage current in a soldering iron, use an isolation transformer. If an isolation transformer is not available, you should bring the iron to soldering temperature, remove it from the a.c. outlet, and then apply it to the part to be soldered.

When soldering or unsoldering transistors or other semiconductor devices, exercise caution to avoid overheating the devices. If necessary, use heat sinks.

CHAPTER 5

AUTOMATIC DEGAUSSING

Automatic degaussing equipment is now installed in all new construction ships which have coil currents that must be changed whenever the ship's heading changes. Most automatic degaussing equipment aboard Navy ships provides automatic compensation for the induced magnetization due to changes in the ship's heading.

This chapter discusses automatic degaussing equipment using the SSM system as a representative system. You will find the basic principles of degaussing in *Electrician's Mate 3 & 2,* NAVEDTRA 10546-D.

SSM AUTOMATIC DEGAUSSING SYSTEM

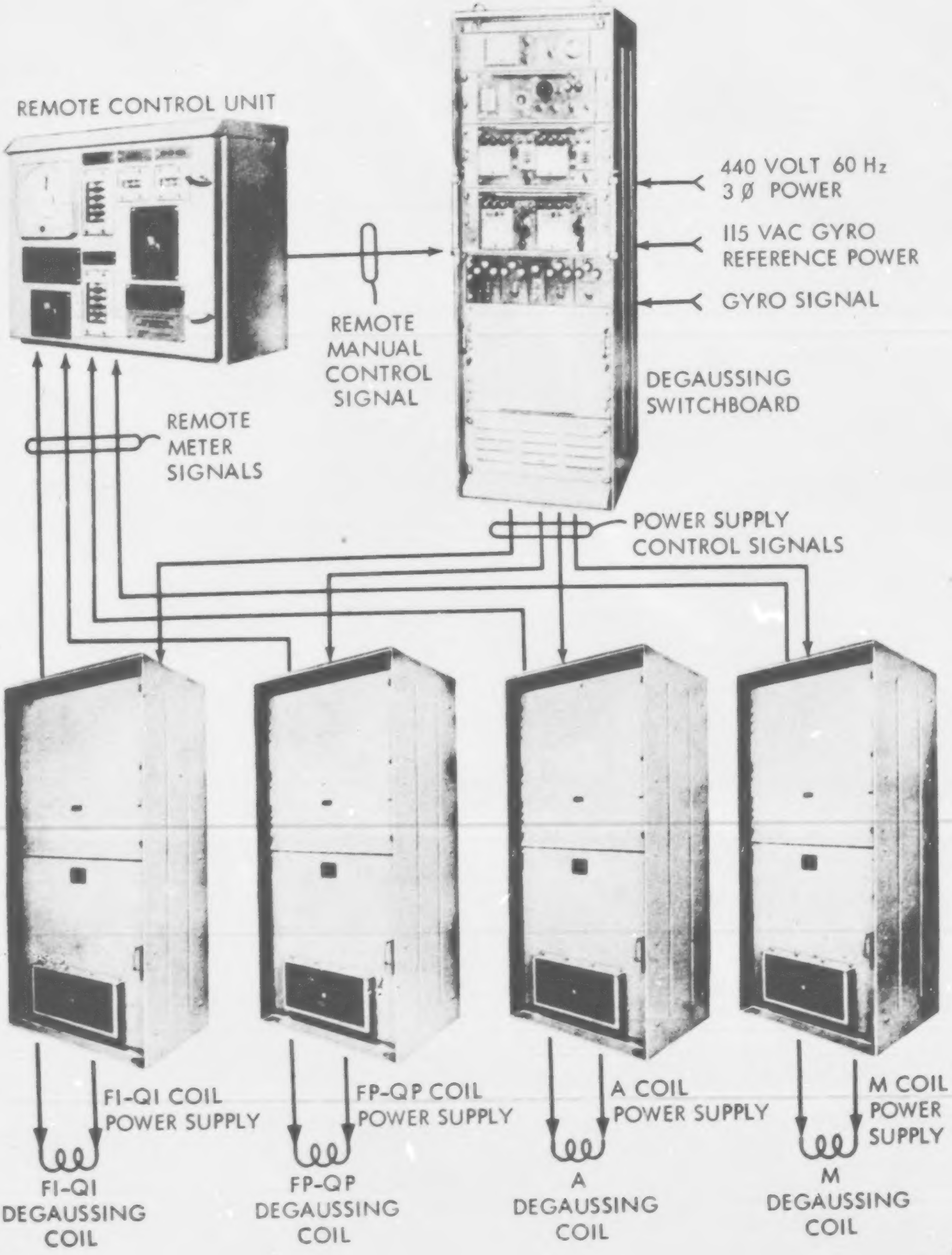
The SSM Automatic Degaussing Control System is a new standard system installed on all new steel-hulled ships which require degaussing. It differs from older systems in the way the current is controlled and sent to the degaussing coils. The SSM uses solid state devices for control and power amplification instead of magnetic amplifiers. The silicon controlled rectifier has taken over many tasks that magnetic amplifiers performed in the older systems. A brief description of the SSM follows.

The SSM (fig. 5-1) is made up of the degaussing switchboard, FI-QI coil power supply, FP-QP coil power supply, A coil power supply, M coil power supply, and a remote control unit. The magnitude and polarity of the current in the A and the FI-QI degaussing coils is automatically controlled by the control circuits in the degaussing switchboard as a function of the ship's magnetic heading. The ship's gyrocompass equipment provides the heading information to the control circuits. The magnitude and polarity of the currents to the FP-QP and M degaussing coils are manually set by controls mounted on the degaussing switchboard.

DEGAUSSING SWITCHBOARD

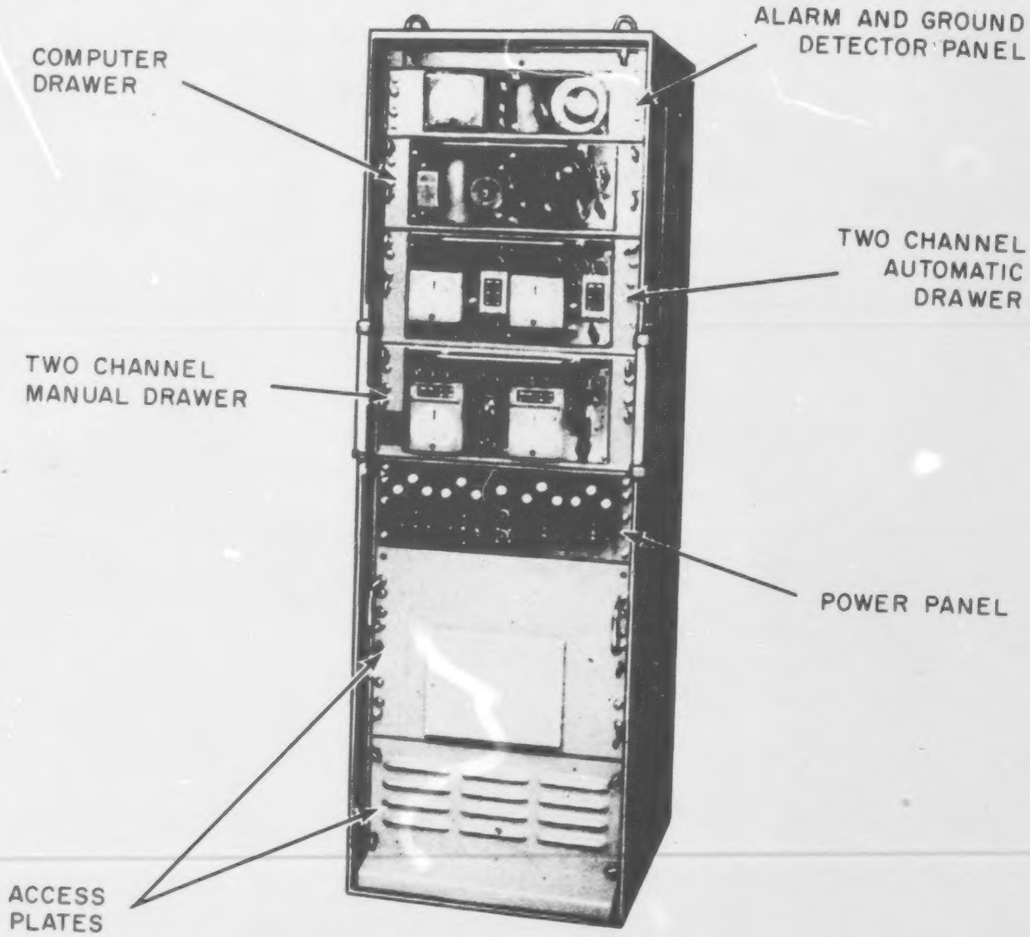
The degaussing switchboard (fig. 5-2) contains the switching and control circuits required for automatic and manual control of the degaussing current output of the FI-QI, FP-QP, M and A coil power supplies. These circuits are mounted in drawers or on panel assemblies in the switchboard enclosure. The drawers and panels mounted in the degaussing switchboard are: the computer drawer, the two-channel automatic drawer; the alarm and ground detector panel; the two-channel manual drawer; and the power panel. There are two access panels for front access to chassis-mounted fuses and terminal boards.

As illustrated in the block diagram (fig. 5-3), the SSM controls the current in four separate degaussing coils of the ship. The circuit controlling the degaussing current in each coil is independent of the other three coil circuits. However, the 440-volt primary power and the ground detector and alarm circuit are tied into all four coil circuits. The M and the FP-QP channels, are manually controlled. The polarity and magnitude of the current to these coils is set to values specified in the ship's degaussing folder for the ship's zone of operation. The automatically controlled channels (FI-QI and A coil channels) are similar to the manually controlled channels except that provisions are made in the control circuits to automatically change the magnitude and polarity of the


REMOTE CONTROL UNIT
440 VOLT 60 Hz 3 Ø POWER
115 VAC GYRO REFERENCE POWER
GYRO SIGNAL
REMOTE MANUAL CONTROL SIGNAL
DEGAUSSING SWITCHBOARD
REMOTE METER SIGNALS
POWER SUPPLY CONTROL SIGNALS
FI-QI COIL POWER SUPPLY
FP-QP COIL POWER SUPPLY
A COIL POWER SUPPLY
M COIL POWER SUPPLY
FI-QI DEGAUSSING COIL
FP-QP DEGAUSSING COIL
A DEGAUSSING COIL
M DEGAUSSING COIL

111.124

Figure 5-1.–SSM automatic degaussing control system.


ALARM AND GROUND DETECTOR PANEL
COMPUTER DRAWER
TWO CHANNEL AUTOMATIC DRAWER
TWO CHANNEL MANUAL DRAWER
POWER PANEL
ACCESS PLATES

111.124.1

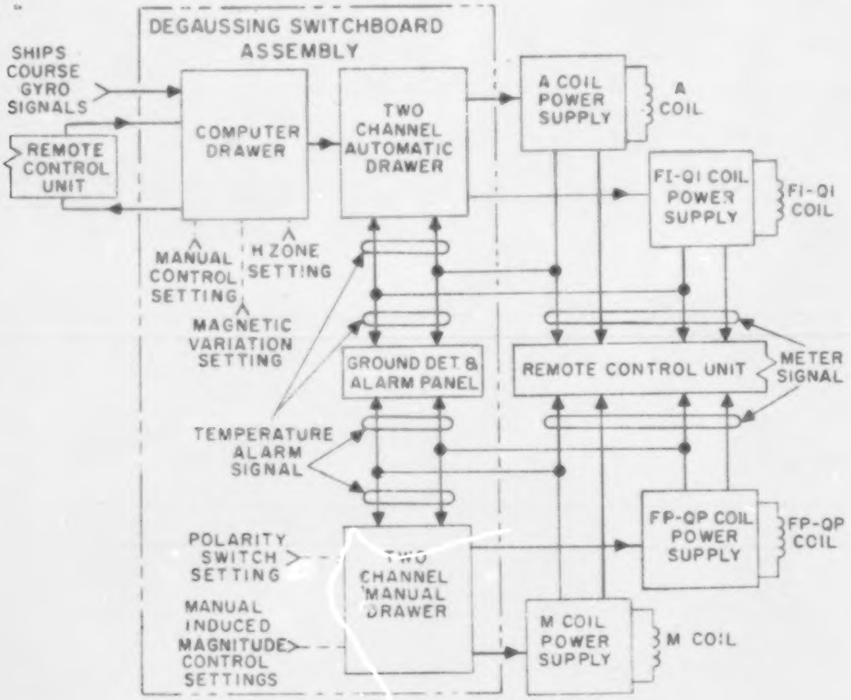
Figure 5-2.—Switchboard.

degaussing current with changes in the ship's magnetic heading.

Manual Coil Channel Control Circuits

The circuits which control the current in the M and the FP-QP manual coil channels are located in the manual drawer (fig. 5-4) and are used to adjust and monitor the degaussing current in the two manual coils. The circuitry for these two coils is identical electrically; therefore, the description following applies to each.

Each section of the manual drawer receives its control power from a separate power transformer. The two secondary windings furnish a.c. power to the indicator lights of the channel and the manual d.c. power supply. The transformer primary receives power from the ship's 440 volt a.c. power through the channel's main power contactor. A rectifier supplies


DEGAUSSING SWITCHBOARD ASSEMBLY
SHIPS COURSE GYRO SIGNALS
REMOTE CONTROL UNIT
COMPUTER DRAWER
TWO CHANNEL AUTOMATIC DRAWER
A COIL POWER SUPPLY
A COIL
FI-QI COIL POWER SUPPLY
FI-QI COIL
MANUAL CONTROL SETTING
H ZONE SETTING
MAGNETIC VARIATION SETTING
GROUND DET & ALARM PANEL
REMOTE CONTROL UNIT
METER SIGNAL
TEMPERATURE ALARM SIGNAL
POLARITY SWITCH SETTING
MANUAL INDUCED MAGNITUDE CONTROL SETTINGS
TWO CHANNEL MANUAL DRAWER
FP-QP COIL POWER SUPPLY
FP-QP COIL
M COIL POWER SUPPLY
M COIL

111.127

Figure 5-3.—Overall functional block diagram.

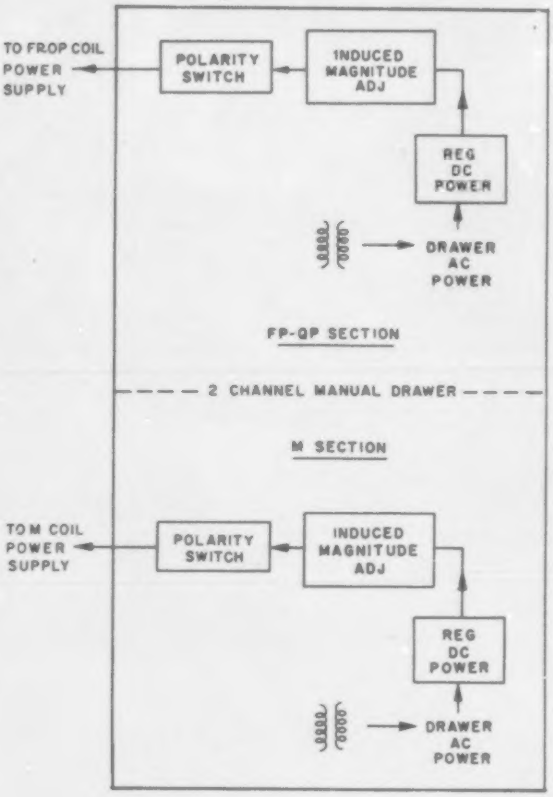
filtered d.c. voltage which is regulated and applied to the channel's induced magnitude control where the signal voltage, proportional to the magnitude of the coil current, is set manually. The proper polarity for the degaussing coil current is selected by the manual push-to-operate switch.

Automatic Coil Channel Control Circuits

The circuits which control the current in the A and the FI-QI automatic coil channels (fig. 5-5) are located in the computer drawer and the automatic coil drawer.

The control circuits of the two automatic channels are independent of each other with the exception of the gear train, H-zone circuit, and magnetic variation circuits of the computer drawer. The following description applies to both channels except where differences are pointed out.

The automatic coil channels normally contain control signals from the computer circuit which operate in response to the true heading signals from the ship's gyro. The true heading signal must be modified by the magnetic variation to obtain the magnetic heading signals necessary to compute the required degaussing currents. The computer gear train is operated by the servomotor which positions a resolver at an angle equal to the magnetic heading angle. The servoamplifier drives the servomotor until the gear train angle equals the angle of the ship's magnetic heading. Regulated a.c. voltage is applied to the gear train resolver which supplies two a.c. output signals: a cosine function of the magnetic heading for controlling the FI-QI coil channel, and a sine function for controlling the A channel.



111.128

Figure 5-4.—Manual coil channel control circuits block diagram.

The FI-QI and A coil demodulators convert the a.c. output signals of the resolver to d.c. signals which are sent through the H-zone selector network and become H cos A (FI-QI coil) and H sine A (A coil). These are the degaussing function signals that ultimately control the degaussing current in the FI-QI coil and the A coil.

The automatic induced magnitude control is a voltage divider which sets the maximum control signal or gain of the control circuit. The signal from the automatic control circuit is amplified (for the loading effect of the power supply circuits) by the operational amplifier. The operational amplifier provides current gain only. To provide indication of a possible failure in the operational amplifier circuit, a signal excess error amplifier is connected to compare the input and output signals. In the event the signals are not of equal voltage, the signal excess error light is energized.

The automatic coil channels have an alternate mode of operation which is employed in the event of failure in the computer drawer or in the ship's gyro. In such an event, the Auto-Manual Switch must be set to MANUAL and the Degaussing Coil Heading Switch set to the position closest to the ship's magnetic heading. The switch applies a positive, negative, or zero signal to the manual induced magnitude control which is connected to the input side of the operational amplifier. In the A-coil channel only, a separate perm circuit applies a manually set d.c. signal to the operational amplifier input.

POWER SUPPLY

The reversible 5-volt d.c. control signal from each coil channel control circuit is interconnected to the power supply for that coil. The 4-channel power supplies of the SSM system are identical electrically; therefore, the description given here applies to all channels, see figure 5-6.

The control signal input is applied directly to the power supply circuits which are polarity sensitive—the Switching Amplifier and the Excess Error Amplifier. The single-ended Mixer Amplifier (mixer and pulse circuit) is connected through reversing contacts on the pilot relay which presents a constant polarity signal to the inputs of this circuit.

The Mixer Amplifier is a magnetic amplifier, used because of its ability to isolate several d.c. control signals. In this stage, the control signal is mixed with current feedback derived from the filtered, constant polarity part of the output circuit. The output of the Mixer Amplifier is a full-wave rectified signal of fixed polarity. The magnitude of the output is modified by current feedback from the output circuit, resulting in improved response and accuracy of the degaussing coil current.

The Pulse Circuit is driven by the output of the Mixer Amplifier and supplies time controlled firing pulses for the SCR Driver Circuit which, in turn, drives the power stage circuit.

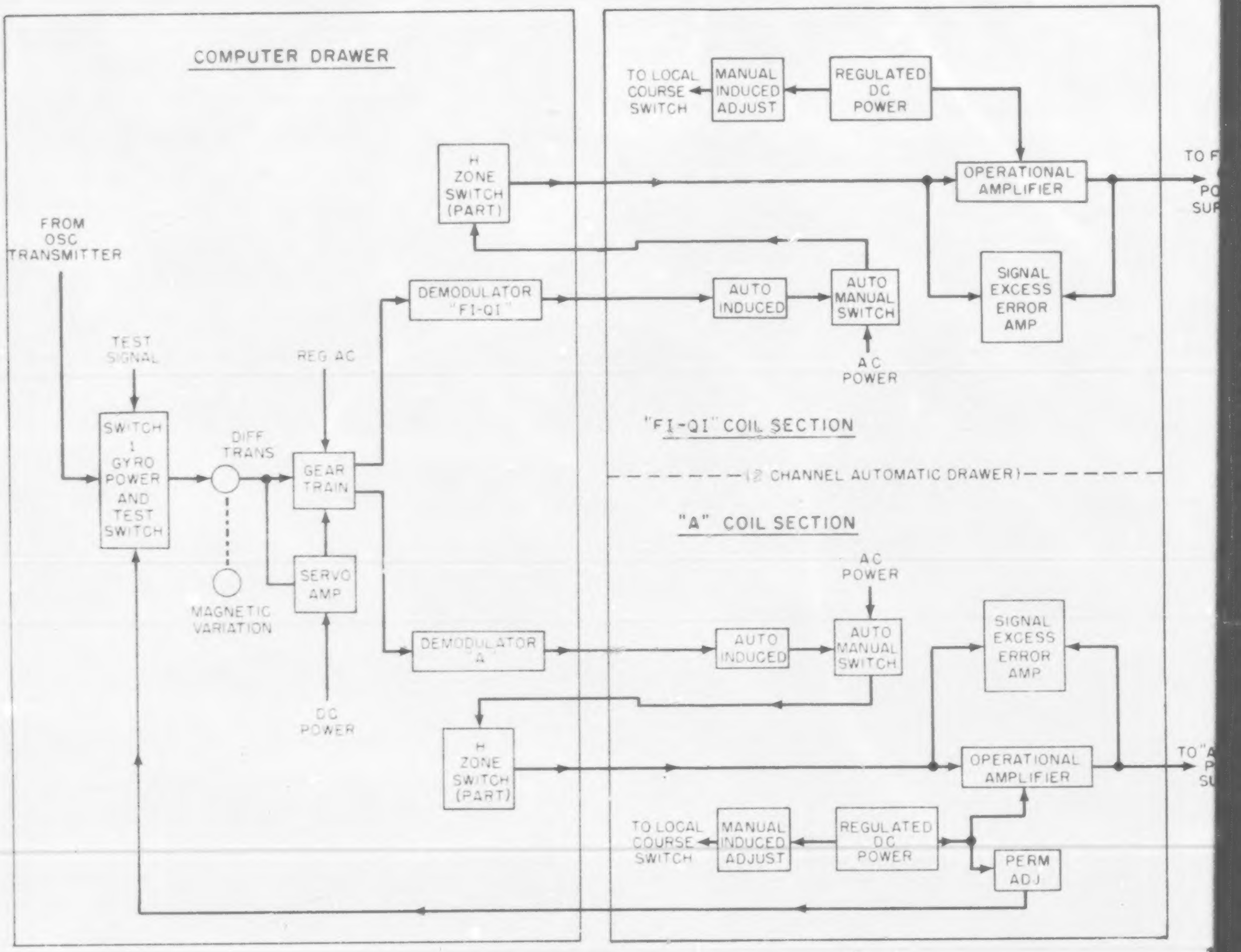
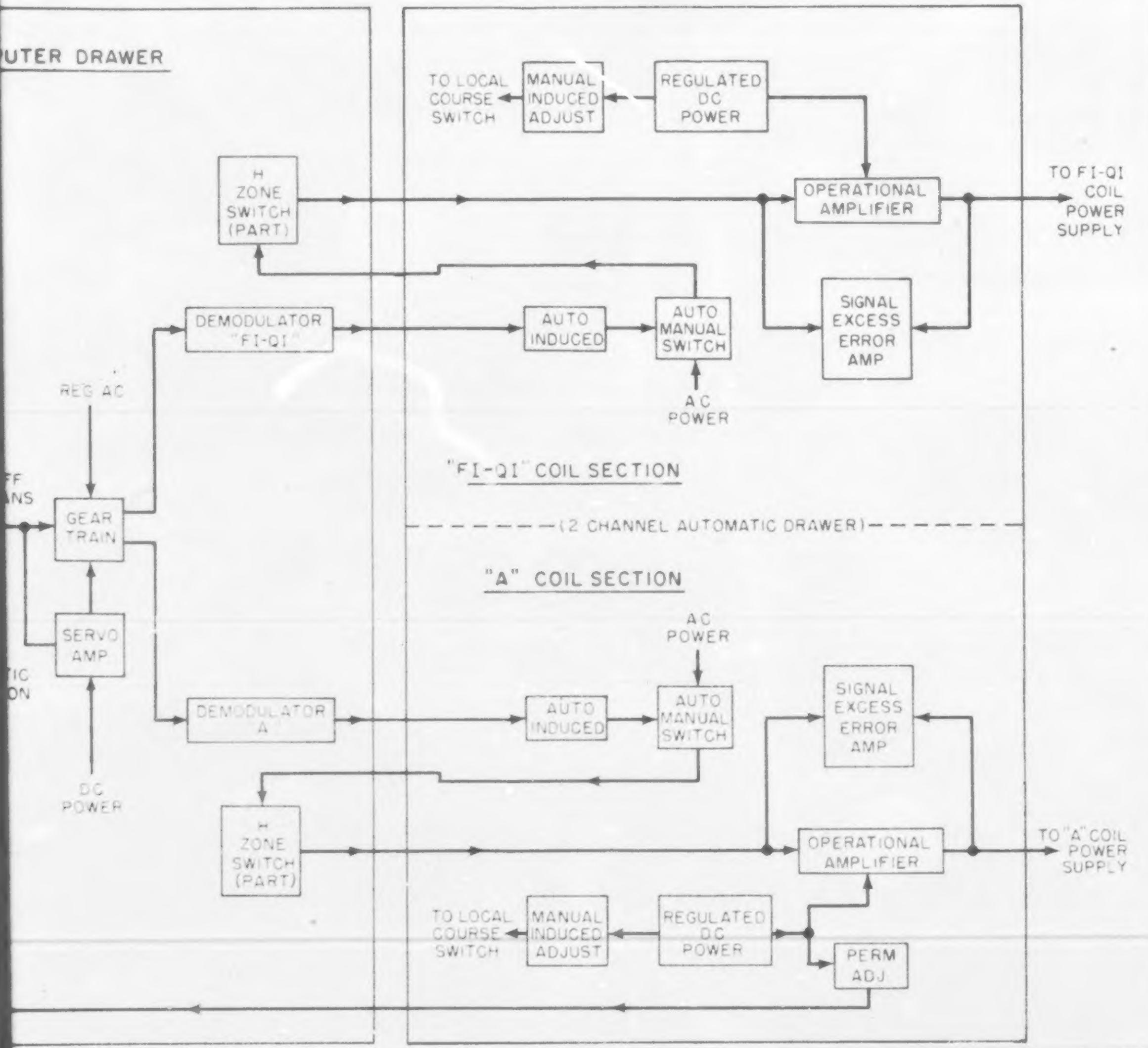

COMPUTER DRAWER
FROM OSC TRANSMITTER
TEST SIGNAL
SWITCH 1 GYRO POWER AND TEST SWITCH
DIFF TRANS
MAGNETIC VARIATION
REG AC
GEAR TRAIN
SERVO AMP
DC POWER
DEMODULATOR "FI-QI"
DEMODULATOR A
H ZONE SWITCH (PART)
H ZONE SWITCH (PART)
TO LOCAL COURSE SWITCH
MANUAL INDUCED ADJUST
REGULATED DC POWER
OPERATIONAL AMPLIFIER
TO F
PO
SUF
SIGNAL EXCESS ERROR AMP
AUTO INDUCED
AUTO MANUAL SWITCH
AC POWER
"FI-QI" COIL SECTION
(2 CHANNEL AUTOMATIC DRAWER)
"A" COIL SECTION
AC POWER
AUTO INDUCED
AUTO MANUAL SWITCH
SIGNAL EXCESS ERROR AMP
OPERATIONAL AMPLIFIER
TO "A
P
SU
TO LOCAL COURSE SWITCH
MANUAL INDUCED ADJUST
REGULATED DC POWER
PERM ADJ

Figure 5-5.—Automatic coil channel control circuits block diagram.


UTER DRAWER
TO LOCAL COURSE SWITCH
MANUAL INDUCED ADJUST
REGULATED DC POWER
H ZONE SWITCH (PART)
OPERATIONAL AMPLIFIER
TO FI-QI COIL POWER SUPPLY
DEMODULATOR "FI-QI"
AUTO INDUCED
AUTO MANUAL SWITCH
SIGNAL EXCESS ERROR AMP
A C POWER
REG AC
FF
ANS
GEAR TRAIN
SERVO AMP
TIC
ON
DC POWER
"FI-QI" COIL SECTION
(2 CHANNEL AUTOMATIC DRAWER)
"A" COIL SECTION
A C POWER
DEMODULATOR A
AUTO INDUCED
AUTO MANUAL SWITCH
SIGNAL EXCESS ERROR AMP
H ZONE SWITCH (PART)
OPERATIONAL AMPLIFIER
TO "A" COIL POWER SUPPLY
TO LOCAL COURSE SWITCH
MANUAL INDUCED ADJUST
REGULATED DC POWER
PERM ADJ

111.129

Figure 5-5.—Automatic coil channel control circuits block diagram.

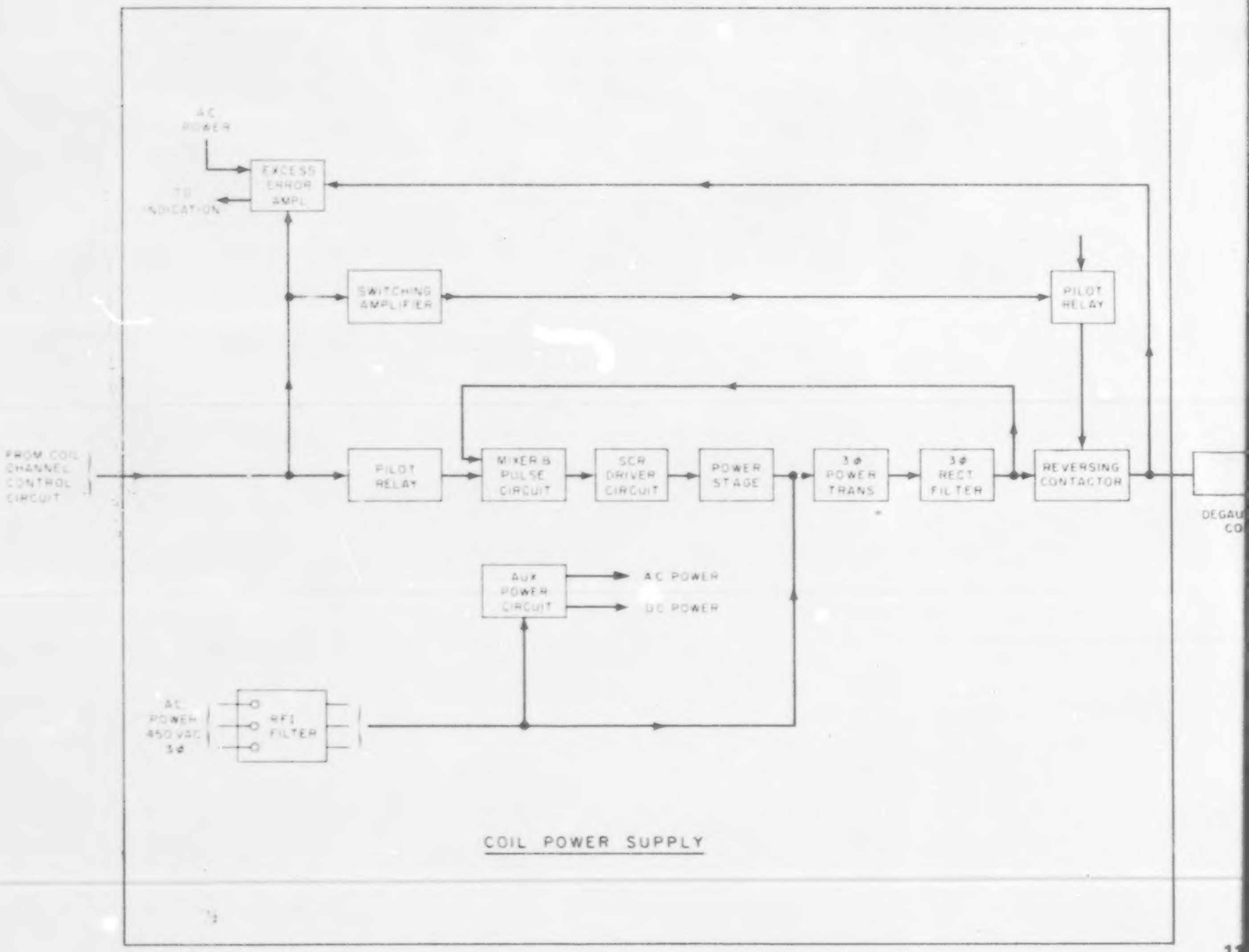
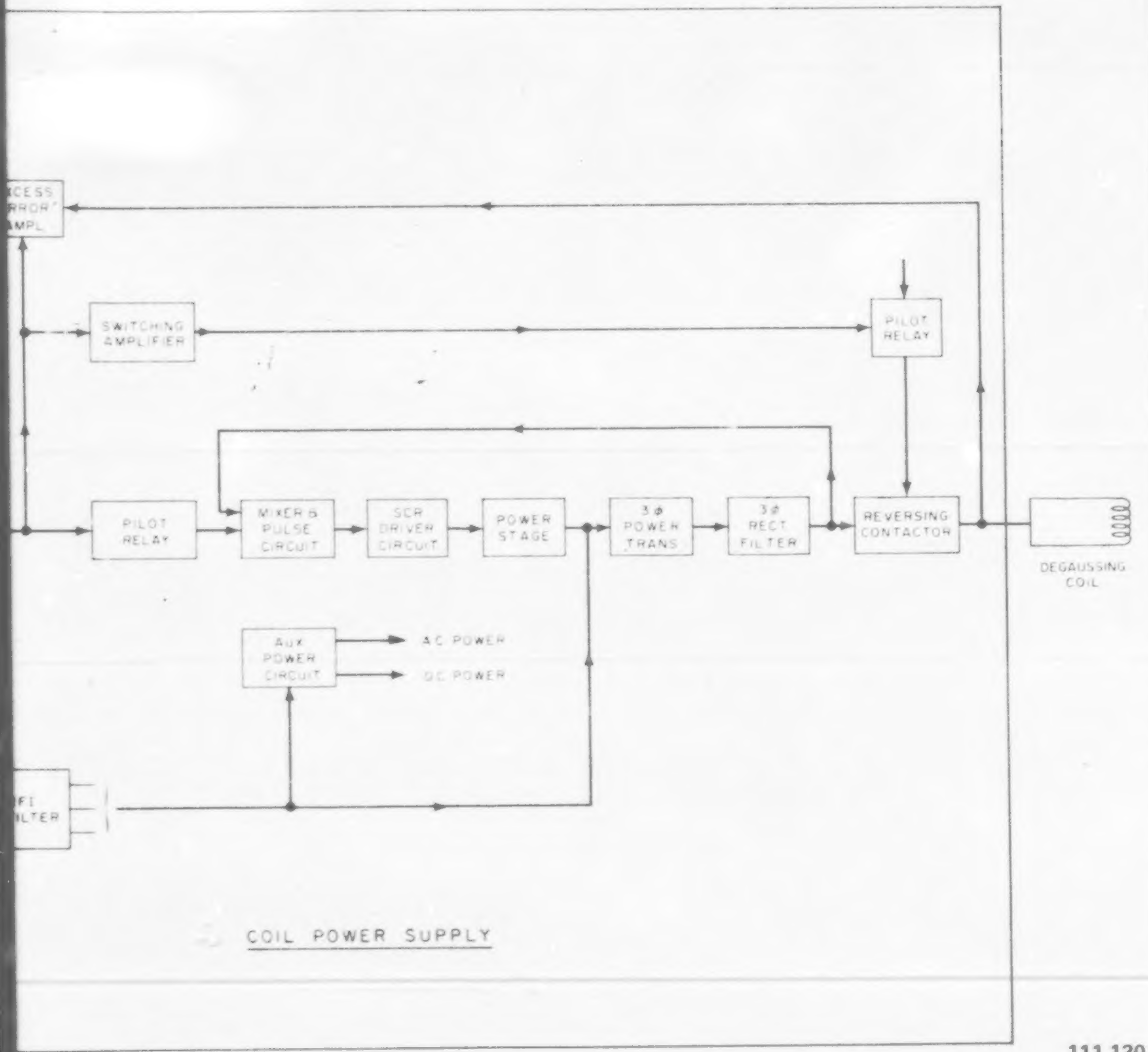

AC POWER
EXCESS ERROR AMPL
TO INDICATION
SWITCHING AMPLIFIER
PILOT RELAY
FROM COIL CHANNEL CONTROL CIRCUIT
PILOT RELAY
MIXER & PULSE CIRCUIT
SCR DRIVER CIRCUIT
POWER STAGE
3 φ POWER TRANS
3 φ RECT FILTER
REVERSING CONTACTOR
DEGAU
CO
AUX POWER CIRCUIT
AC POWER
DC POWER
AC POWER 450 VAC 3 φ
RFI FILTER
COIL POWER SUPPLY
11

Figure 5-6.—Coil power supply block diagram.


CESS
RROR
AMPL
SWITCHING AMPLIFIER
PILOT RELAY
PILOT RELAY
MIXER & PULSE CIRCUIT
SCR DRIVER CIRCUIT
POWER STAGE
3ø POWER TRANS
3ø RECT FILTER
REVERSING CONTACTOR
DEGAUSSING COIL
AUX POWER CIRCUIT
AC POWER
DC POWER
FI
LTER
COIL POWER SUPPLY

111.130

Figure 5-6.—Coil power supply block diagram.

The SCR Driver Circuit is the intermediate stage between the Pulse Circuit and the output SCR's (Power Stage). It supplies sustained firing pulses of the current level and phase relationship required by the Power Stage Circuit.

The Power Stage Circuit consists of six silicon controlled rectifiers (SCR's). A pair of SCR's is connected in parallel with each other and in series with each of the primary windings of a delta connected 3-phase power transformer. The SCR's in the Power Stage Circuit are turned ON by the firing pulses generated by the SCR Driver Circuit. The firing pulses are of the current level and phase required to deliver the proper power to the degaussing coil. Thus, by turning the SCR's ON and OFF at a preset rate and time duration, the current through the primary windings of a 3-phase transformer is controlled, which in turn controls the power to the degaussing coil. This 3-phase power transformer steps the voltage down to the proper value. The secondary winding is tapped to allow matching of the supply to a wide range of degaussing coil load resistances.

The secondary power is rectified, filtered, and then connected to the degaussing coil in the proper polarity as determined by the Reversing Contactor. The Reversing Contactor is energized according to the control signal polarity by the pilot relay which is, in turn, operated by the Switching Amplifier.

The Excess Error Amplifier is included in each power supply to provide indication of a fault in that supply. This circuit compares the control signal to the supply with a sample of the degaussing coil current and energizes an indicator light circuit when the power supply output is not proportional to the control signal.

DEGAUSSING REMOTE CONTROL UNIT

The remote control unit (fig. 5-7) contains circuitry necessary for monitoring the system operation and for manually controlling the FI-QI and A coils from a location remote to the switchboard. An ammeter on the unit is provided with the Meter Selector Switch which selects the coil current to be monitored. The degaussing coil Heading Switch is provided for control of the FI-QI and A coil from the remote control unit when the automatic coils are in the manual operation mode. Various lights are mounted, as shown, for system monitoring.

MAINTENANCE

Preventive maintenance should be performed as indicated on the MRC's for the SSM system to insure proper system operation and to minimize the possibility of future failure. In addition, it should be noted that system operation can be impaired by defective degaussing coils.

For personnel and equipment safety when removing drawers from the switchboard, remember that each drawer weighs more than 50 pounds and take appropriate precautions.

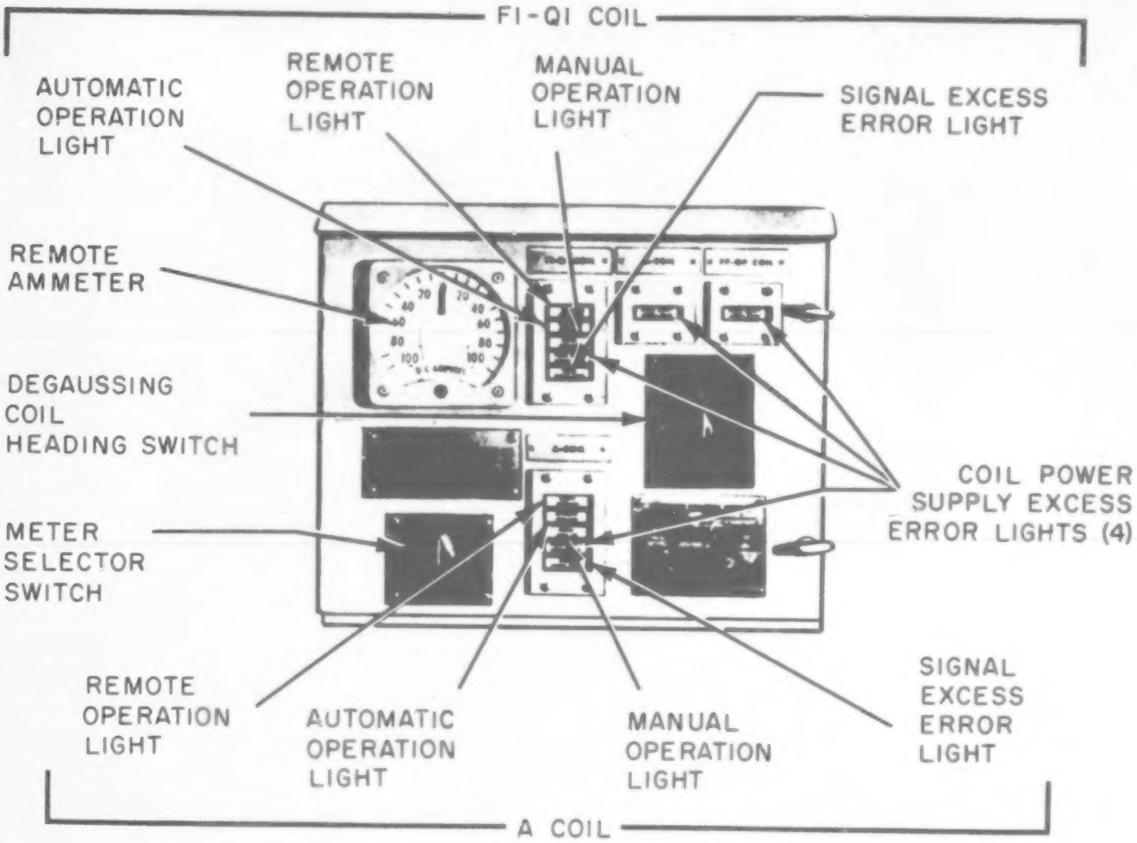
When working with the power supplies discharge all capacitors and RFI filters between their terminals and between the terminals and ground to prevent dangerous shock to yourself and others.

To prevent damage to the printed circuit card semiconductor components due to transient voltages, be sure to turn off the unit power before removing or replacing the card. No repairs or adjustments (except as noted in the technical manual) should be made aboard ship, except in case of emergency, because the cards are a depot level maintenance item and are critical for safe operation of the degaussing system.

TROUBLESHOOTING

The SSM Automatic Degaussing Control System uses modularized packaging concepts which are new to degaussing systems. Therefore, there is very little historical data available to aid in system troubleshooting so a logical method technique has been designed to aid in recognizing and locating a system malfunction.

The ability to recognize that there is a malfunction is based on a thorough and comprehensive understanding of the characteristics of the degaussing system and operating indications. For example, during normal operation the first sign of trouble could be the illumination of a red or amber light, the


FI-QI COIL
AUTOMATIC OPERATION LIGHT
REMOTE OPERATION LIGHT
MANUAL OPERATION LIGHT
SIGNAL EXCESS ERROR LIGHT
REMOTE AMMETER
DEGAUSSING COIL HEADING SWITCH
COIL POWER SUPPLY EXCESS ERROR LIGHTS (4)
METER SELECTOR SWITCH
REMOTE OPERATION LIGHT
AUTOMATIC OPERATION LIGHT
MANUAL OPERATION LIGHT
SIGNAL EXCESS ERROR LIGHT
A COIL

111.126

Figure 5-7.—Remote control unit controls and indicators.

ringing of the HIGH TEMPERATURE ALARM bell, an abnormal meter reading for one of the degaussing coils, or the illumination of a blown fuse indicator.

Once a trouble is known to exist, you should observe all indications and controls for normal or abnormal indications. In some cases, what you thought was a system malfunction may turn out to be an incorrect control setting. For instance, the first indication may be a zero current on the M COIL meter (incorrect for the ship's particular location). But observation of the rest of the indicators and controls may show that the M COIL POWER light is extinguished and that the power switch is OFF. Thus, what initially was thought to be a system malfunction was actually a control setting error.

After recognizing that a fault exists and noting all symptom indications, you should formulate a number of logical choices as to the cause and likely location of the trouble. The choices are based on knowledge of the equipment operation, full identification of the trouble symptom, and the information contained in the technical manual for the system.

Check the probable fault sources in the order that will require the least amount of time. If the first source you check does not prove to be the malfunction, check the next suspected section and so on until you locate the faulty functional section.

After you determine which section is malfunctioning, you must locate the printed circuit card, the control, or the other replaceable unit responsible for the trouble.

Before reenergizing the equipment, be certain that the failed unit you found is actually the malfunction, and not just the result of the malfunction.

CHAPTER 6

GYROCOMPASSES

A gyrocompass is a device which uses the gyroscopic principle to obtain an indication of true north. The gyrocompass system develops own ship's heading and transmits the heading to various navigation and weapons stations, and to other equipment throughout the ship. Gyrocompasses are identified by the mark-mod system. The mark (Mk) number designates a major development of a compass. The modification (Mod) number indicates a change to the major development.

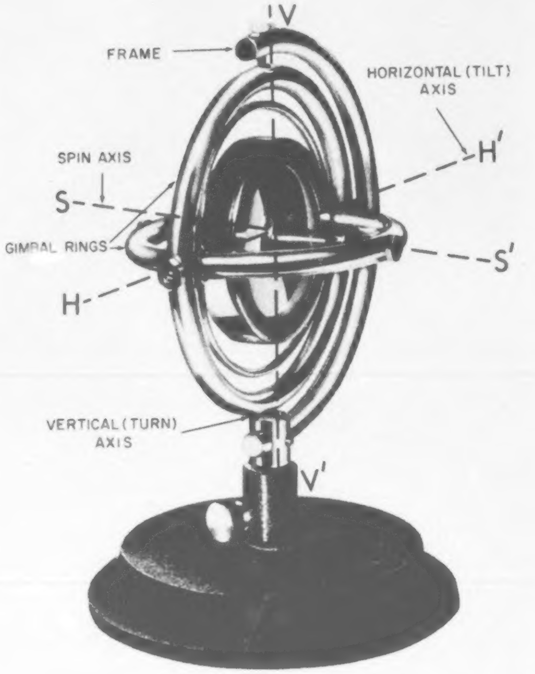
All gyrocompasses depend on the principles of the gyroscope, gravity, and earth's rotation for their operation. This chapter discusses gyroscopic principles and their applications to obtain a functional gyrocompass system. We will skim only the top of this system in our discussion so that supervisory personnel will have better communication with the operators and repairmen who are assigned to the systems. You may obtain additional information from current editions of *Synchro, Servo and Gyro Fundamentals*, NAVEDTRA 10105; *IC Electrician 3 & 2*, NAVEDTRA 10558; *IC Electrician 1 & C*, NAVEDTRA 10557; and the manufacturer's manual for your specific installation.

There are two basic types of gyrocompasses in use at the present time. They are typed according to the way the torques are developed and applied to control the sensitive elements. The older electrical/mechanical type is in the process of being replaced by the electrical/electronic type. In this chapter the Sperry Mk 11 Mod 6 gyrocompass will represent the electrical/mechanical type and the Sperry Mk 19 will represent the electrical/electronic type. While there is more than one type of each compass, the functional description of these two compasses will explain the two basic types of systems.

After studying this chapter, you should be able to describe the action of a free gyroscope, to tell how it is converted into either an electrical/mechanical or an electrical/electronic gyrocompass, to give a brief functional description of the Sperry Mk 11 Mod 6 and the Mk 19 gyrocompasses, and to supervise the operator and repair personnel in training, maintenance, repair, and records pertaining to this equipment.

THE FREE GYROSCOPE

The gyroscope is a heavy wheel, or rotor, suspended so that its axle is free to turn in any direction. The rotor axle is supported by two bearings at S and S′ in a ring, as illustrated in figure 6-1. The ring is supported by studs and bearings at H and H′, in a slightly larger outer ring. The outer ring is mounted in the supporting frame by studs and bearings at V and V′. The two supporting rings are called gimbals. The supporting frame is not a part of the gyroscope but merely supports it. The rotor and the two gimbals are balanced about their axis, which are mutually perpendicular and intersect at the center of gravity of the rotor. The bearings of the rotor and gimbals are considered to be completely free of friction. Actually, there is always some friction, but it has been reduced to such an extent that it is considered nonexistent.



77.194

Figure 6-1.—The gyroscope.

THREE DEGREES OF FREEDOM

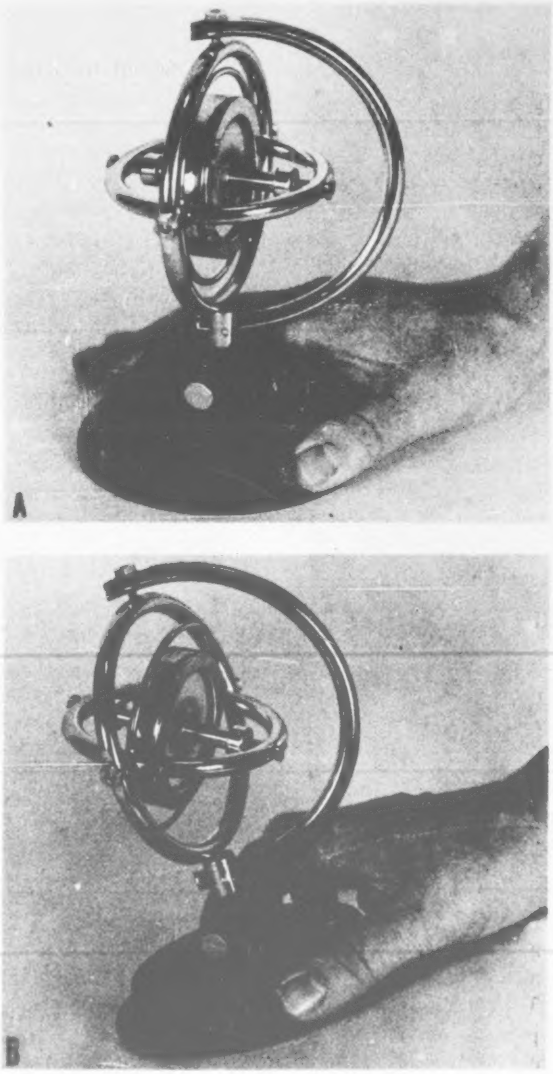
The gyroscope rotor has three degrees of freedom—freedom to spin, freedom to turn, and freedom to tilt—which permits the rotor to assume any position within the supporting frame (fig. 6-1). The rotor is free to spin about its own axle (spinning axis S-S')—, the first degree of freedom. The inner gimbal ring is free to rotate on its bearings about the horizontal axis (H-H')—the second degree of freedom. The outer gimbal ring is free to rotate on its bearings about the vertical axis (V-V')—the third degree of freedom.

GYROSCOPIC PROPERTIES

When a gyroscope rotor is spinning rapidly, the gyroscope develops two properties that it does not have when the rotor is at rest. These two properties, which make it possible to develop the gyroscope into a gyrocompass, are rigidity of plane and precession.

Rigidity of Plane

When the rotor of a gyroscope is set spinning with its axle pointed in one direction (fig. 6-2A),



27.128(77A)

Figure 6-2.—Rigidity of plane of spinning gyroscope.

the rotor continues to spin with its spin axle pointing in the same direction, no matter how the frame of the gyroscope is tilted or turned (fig. 6-2B). As long as the bearings are frictionless and the rotor spins, no turning of the supporting frame can change the plane of the rotor with respect to space. This property of the gyroscope is known as rigidity of plane, gyroscopic inertia, or stability. It can be explained by Newton's first law of motion which states that a body in motion will continue to move at a constant speed in a straight line unless acted upon by an outside force.

A gyroscope can be made more rigid (1) by making the rotor heavier, (2) by causing the rotor to spin faster, and (3) by concentrating more of the rotor weight near the circumference. If two rotors with cross sections like those shown in figure 6-3 are of equal weight and rotate at the same speed, the rotor in figure 6-3B is more rigid than the rotor in figure 6-3A. This condition exists because the weight of the rotor in figure 6-3B is concentrated near the circumference. Both gyroscope and gyrocompass rotors are shaped like the rotor shown in figure 6-3B.

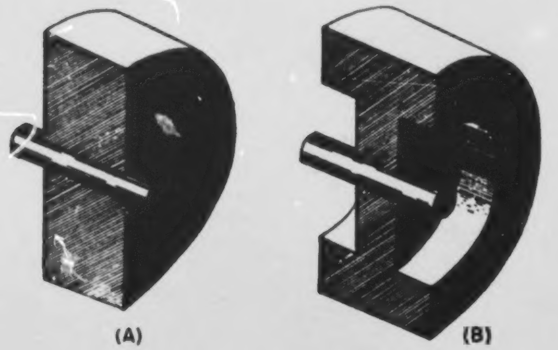


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Figure 6-3.—Weight distribution in rotors.

Precession

We stated earlier that, because of gyroscopic inertia, movements of the outer supporting frame has no effect on the direction in which the spin axle of a spinning gyroscope points. To change this direction, a force must be applied to the gyroscope rotor or its axle. A downward force on one end of the rotor axle attempts to tilt the gyroscope about the horizontal axis and, if the rotor were not spinning, the axle would tilt in response to the force. However, if the rotor is spinning, its rigidity will resist the attempt to tilt the rotor about the horizontal axis, and instead, the gyroscope will turn about the vertical axis. Any force attempting to turn the gyroscope about the vertical axis is similarly resisted and results in a tilt about the horizontal axis.

This rotation of a gyroscope about an axis perpendicular to the axis about which a force is exerted is called precession. Precession takes place whenever any force tends to tilt and/or turn the axle of a spinning gyroscope rotor.

A simple way to determine the direction of precession is illustrated in figure 6-4. Consider the force that tends to change the plane of rotation of the rotor as it is applied to point A at the top of the wheel. This point does not move in the direction of the applied force, but a point displaced 90° in the direction of rotation moves in the direction of the applied force. This is the direction of precession.

Any force that tends to change the plane of rotation causes a gyroscope to precess.

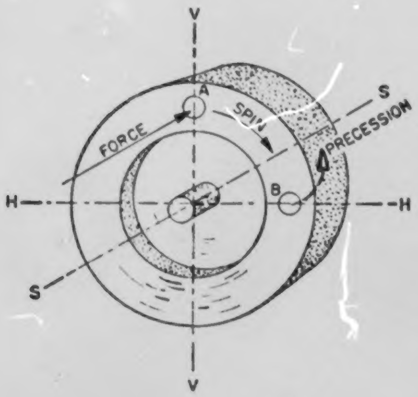

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Figure 6-4.—Direction of precession.

Precession continues as long as there is a component of force acting to change the plane of rotation, and precession ceases immediately when the force is removed. If the plane through which the force is acting remains unchanged, the gyroscope precesses until the plane of the rotor is in the plane of the force. When this position is reached, the force is about the spinning axis and can cause no further precession.

If the plane in which the force acts moves at the same rate and in the same direction as the precession which it causes, the precession will be continuous.

EFFECT OF EARTH'S ROTATION

As explained previously, a free-spinning gyroscope can be moved in any direction without altering the angle of its plane of rotation in respect to a fixed point in space. If a free-spinning gyroscope were placed on the earth's surface at the equator with its spinning axis horizontal and aligned east and west, an observer in space below the south pole (fig. 6-5) would note that the earth rotates clockwise from west to east and carries the gyroscope along. As the earth rotates, rigidity of plane keeps the gyroscope wheel fixed in space and rotating in the same plane at all times. Assume that the gyroscope is set spinning at 0000 hours with its spinning axis aligned east and west and parallel to the earth's surface. At 0600, 6 hours after the gyroscope was started, the earth has rotated 90° and the axle of the gyroscope is still aligned with the original starting position. At 1200 the earth has rotated 180° while the gyroscope still retains its original position. At 1800 the earth has rotated 270° while the gyroscope still retains its original position. At 0000 the earth has rotated 360° and the gyroscope is still in its original position.

Note that throughout the 24-hour period the spin axle of the rotor has maintained a fixed position in space.

This rigidity of plane appears quite differently to an observer standing on the earth's surface. As the earth rotates, the observer moves with it and the gyroscope wheel appears to rotate about its horizontal axis. Figure 6-6 shows how this gyroscope is set spinning at 0000

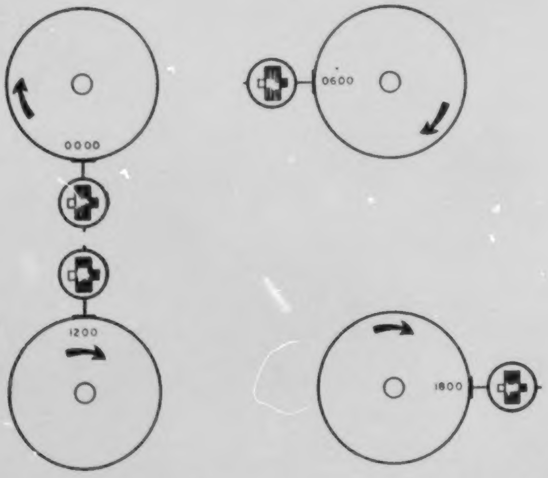

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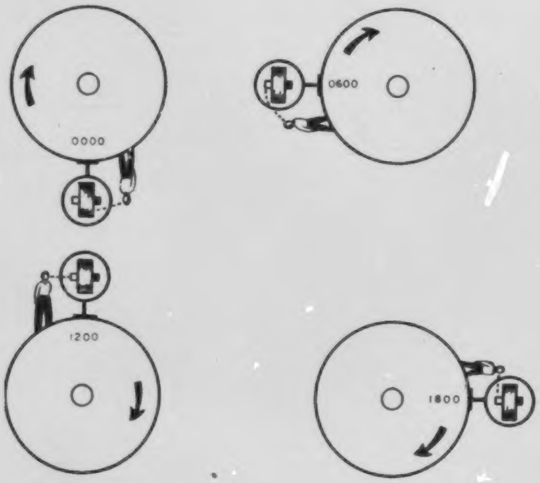
Figure 6-5.—Free gyroscope at the equator as viewed from space below the south pole.



12.144(77A)B

Figure 6-6.—Free gyroscope at the equator viewed from the earth's surface.

hours with its spinning axis horizontal and pointing westward toward the observer. At 0600, 6 hours after the gyroscope was started, the earth has rotated 90° and the gyroscope axle apparently has tilted. To the observer, the axle points straight down and is vertical to the earth's surface. At 1200 the gyroscope axle is horizontal again, but the axle points away from the observer. At 1800 the gyroscope axle is again vertical and points straight up. At 0000 the earth has rotated 360° and the gyroscope axle appears to the observer to be back in its original position while in fact it has been fixed in space for the entire period.

The rotation of the gyroscope axle as seen by the observer on the earth's surface is known as apparent rotation. Apparent rotation is caused by rigidity of plane which tends to maintain the plane of the gyroscope wheel parallel to its original position in space. Apparent rotation, or tilt of the gyro horizontal axis, is referred to as horizontal earth rate effect. This effect varies with the cosine of the latitude and is maximum at the equator and zero at the poles.

Now assume that the spinning gyroscope, with its spinning axis horizontal, is moved to the north pole (fig. 6-7). To an observer in space above the north pole, it is seen that the gyroscope axle remains fixed and the earth rotates under it. To an observer on the earth's surface the gyroscope appears to rotate about its vertical axis. This apparent rotation about the vertical axis is referred to as vertical earth rate effect and it varies with the sine of the latitude. It is maximum at the poles and zero at the equator.

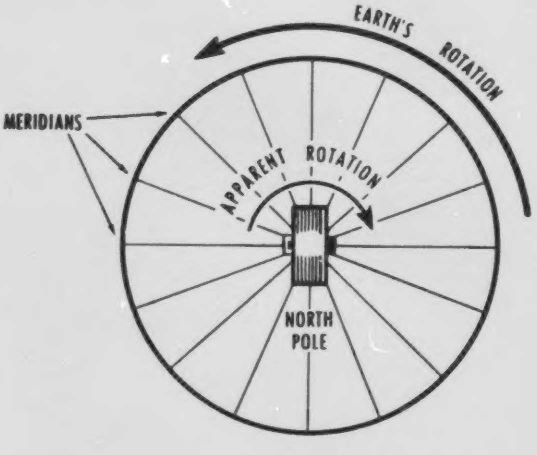


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Figure 6-7.—Apparent rotation of a gyroscope at the north pole.

When the gyroscope axle is placed parallel to the earth's axis at any location on the earth's surface, the apparent rotation is about the spin axle of the gyroscope and cannot be observed. At any point between the equator and either pole, a gyroscope whose spinning axis is not parallel to the earth's spinning axis has an apparent rotation that is a combination of horizontal earth rate and vertical earth rate.

CONVERTING THE GYROSCOPE INTO A COMPASS

If a free gyroscope is set with its spinning axle in the plane of the meridian and parallel to the earth's axis, it will remain in that position because the apparent rotation produced is about the gyroscope axle. Thus, it becomes a direction-indicating device. Once set, it continues to point north as long as no disturbing forces cause it to precess out of the plane of the meridian. Such an instrument, however, is not useful as a compass because any slight friction sets up torques that cause it to precess away from the meridian. An excessive tilt in relation to the earth's surface, except at or near the equator, is required to keep the gyroscope axle parallel to the earth's axis. Also, if the axle is set sufficiently level for the instrument to be useful as a compass in a north or south latitude, the earth's rotation causes it to turn away from the meridian, as explained in the preceding paragraphs.

The following conditions must be met to make a gyroscope into a gyrocompass which accurately indicates north at all times.

1. Torques of the correct magnitude and direction must be provided to precess the gyroscope so that the spinning axis is brought

parallel to the meridian within a reasonable time after the wheel is set spinning. Correct torques also must be provided to cause precession about the vertical axis at the proper rate and in the proper direction to cancel the effect on the earth's rotation.

2. The spin axis of the gyroscope must be nearly level when parallel to the meridian, and a means must be provided to prevent it from oscillating across the meridian.

The electrical/mechanical (Sperry Mk 11 Mod 6) type gyrocompass employs a mercury ballistic to detect an unlevel condition of the rotor axle and applies the necessary torque about the horizontal axis which causes the compass to precess about its vertical axis and seek the meridian (true North). This torque is applied to the bottom of the rotor case by means of the connection arm and the offset connection bearing stud, hence, the name mechanical gyrocompass.

In its simplest form the mercury ballistic consists of two mercury-containing reservoirs, one mounted at each end of the rotor axle. The two reservoirs are connected by a pipe so that the mercury is free to flow from one reservoir to the other, as shown in figure 6-8.

When the axle is level (fig. 6-8A), each reservoir contains the same amount of mercury, each weighs the same, and each exerts the same downward force on its end of the axle. Therefore, no torque is produced about any axis. When the axle is tilted, even slightly (fig. 6-8B), mercury runs through the connecting tube from the higher container to the lower container. The amount of mercury in the two tanks is no longer equal and the lower tank is heavier because it contains more mercury. Therefore, the lower tank exerts more force against its axle, than does the upper tank, and produces a torque about axis H-H'. This torque, which seemingly tends to increase the tilt, instead causes precession about the vertical axis, V-V'.

The electrical/electronic type gyrocompass uses a gravity reference system consisting of a means to detect an unlevel condition, and the necessary electronic circuitry to amplify and control these signals. The unlevel signal is in the form of an electrical signal, the phase and magnitude of which indicates the direction and the amount of the gyro axle tilt, within design limits.

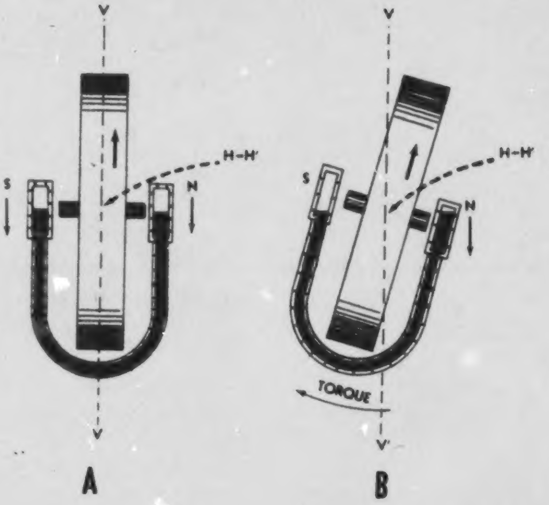

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Figure 6-8.—Action of a mercury ballistic.

There are two kinds of detecting devices presently in use. An electrolytic bubble level is used in the Mk 23, and all mods of the Mk 19 except the 3C and 3D. An accelerometer is used in the Mk 19 Mods 3C and 3D. Both these devices are mounted parallel to the spin axis of the rotor and, therefore, detect any tilt of the spin axle.

The electrolytic bubble level (fig. 6-9) is the most commonly used detecting device. It consists of a slightly curved cylindrical glass vial containing three platinum electrodes situated as shown. The vial is nearly filled with an electrolyte so that a bubble is formed at the top of the vial. When the vial is horizontal, the bubble is centered and the resistance between the top electrode and either of the lower electrodes is equal. If the vial tilts so the bubble moves to the left, there is less electrolyte between the top electrode and the lower-left electrode and the resistance between the two is increased. Correspondingly, the resistance

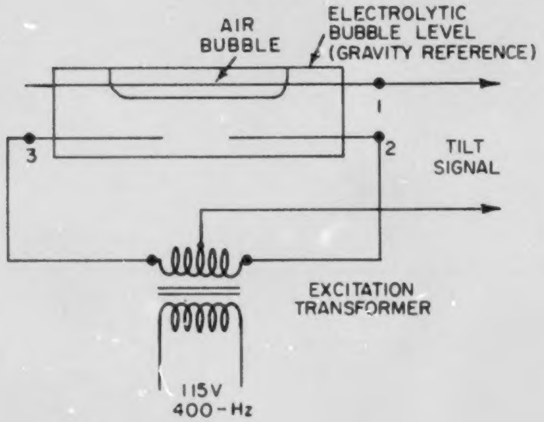

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Figure 6-9.—Electrolytic bubble level simplified schematic diagram.

between the top and lower-right electrodes is less. The difference in resistance is proportional to the movement of the bubble. If the bubble moves to the right, the opposite effect takes place.

As shown in figure 6-9, the two lower electrodes are excited from the opposite ends of the output winding of an excitation transformer whose primary is connected to one phase of the 400-hertz power line. The output signal (tilt signal) of the gravity reference circuit is obtained between an accurately located center-tap (signal common) of the secondary of the excitation transformer and the top electrode of the gravity reference. When the level is horizontal, the output of the gravity reference circuit is zero. As the gravity reference is tilted from the horizontal, an output voltage will be produced which is proportional to the amount of tilt and with the phase dependent upon the direction of tilt. Thus, the gravity reference is employed to produce an output signal with magnitude and phase according to the magnitude and sense of the departure of the rotor spin axle from horizontal.

The signals detected, developed, and amplified by the gravity reference system are applied to the rotor (sensitive element) electromagnetically through devices called torquers to cause the controlled precession of the sensitive element. These torquers operate in pairs and are mounted on opposite sides of the sensitive element. Each torquer is made up of coils wound on an open-E rack made of soft iron laminations. The two end legs act as control fields while the center leg acts as the reference field and is displaced by 90 electrical degrees. They operate similar to a 2-phase induction motor to place a turning torque on the sensitive element. The amount of torque is proportional to the magnitude of the signal from the gravity reference system to the control windings and the direction depends on whether the voltage is leading or lagging the fixed field. The signal voltage amplified and fed to the torquers provides the necessary torques to make the compass precess to seek and settle on the true meridian. In the electrical/electronic type of gyrocompass the torques are not applied mechanically.

If the torque from the mercury ballistic or gravity reference system were applied only about the horizontal axis, the gyrocompass would oscillate continuously back and forth across the meridian. Thus, the unit would be north-seeking but not north-indicating. The time in minutes for one complete cycle of this movement is called its period of oscillation (usually called its period) and is one of the variables in the design of a gyrocompass.

The period on a north-seeking gyro is determined (1) by the weight, size, and shape of the rotor, (2) by the rotor speed, (3) by the torque developed by the mercury ballistic or the gravity reference system azimuth torquer and (4) by the latitude. If a short period (of oscillation) is used, the gyrocompass is too greatly disturbed by ship motions, such as roll, pitch, and speed or course changes. Too long a period (of oscillation), however, causes the compass to take an excessive amount of time to settle on the meridian after starting or after a disturbance.

The north-seeking gyro will never settle on the meridian. Therefore, a means must be provided to suppress, or damp, the oscillations by reducing the size of successive swings past the meridian until the oscillating motion is stopped. The damped, north-indicating, gyrocompass will precess at a rate to cancel the effect of the earth's rotation, and therefore give a continuous indication of true north.

The oscillations are damped by applying a small, controlled torque about the vertical axis of the gyrocompass; thereby causing controlled, compound precession about the horizontal axis (north-seeking torque) and the vertical axis (damping/north-indicating torque).

In the electrical/mechanical gyrocompass the dampening torque is applied by offsetting the point of connection between the mercury ballistic and the rotor case a fraction of an inch to the east of the vertical axis. Thus, the torque exerted by the mercury ballistic is applied about both the horizontal axis and the vertical axis.

In the electrical/electronic gyrocompass the dampening torque is obtained by taking a portion of the gravity reference signal and applying a torque electromagnetically about the vertical axis by means of the leveling torquer. Thus, the gravity reference signal developed by the electrolytic bubble level or accelerometer is applied about the horizontal axis by the azimuth control torquer (north-seeking) and about the vertical axis by the leveling torquer (dampening/north-indicating torque). Thus, the gravity reference signal is applied about both the horizontal axis and the vertical axis.

GYROCOMPASS ERRORS

A gyrocompass is subjected to many outside forces which will induce errors. Some of these are the ship's motion, roll, pitch, speed, acceleration, deceleration, whether the ship's direction of travel is adding to or subtracting from the earth rate, the latitude at which the ship is operating, etc.

The different types of gyrocompasses correct for or eliminate these forces in different ways. Some of these errors may not affect a particular type of gyrocompass because of its design, and other errors are compensated for in different ways in different compass systems. Therefore, we will not discuss gyrocompass errors in any depth. Some of the errors that affect a particular system will be explained, with its method of correction or compensation, under the Sperry Mk 11 Mod 6 and the Sperry Mk 19 sections later in this chapter. Generally, however, you will be expected to obtain the information about gyrocompass errors, how they affect your installation, etc, from your manufacturer's technical manual.

SPERRY MK 11 MOD 6 GYROCOMPASS

The Sperry Mk 11 Mod 6 (fig. 6-10) is an electrical/mechanical type gyrocompass that was formerly used extensively on destroyer type ships. Although these compasses are being phased out of service, several are still to be found in the fleet. The complete system consists of the master compass, the control system, alarm system, followup system, and the transmission system. The master compass includes five major components: (1) sensitive element, (2) mercury ballistic, (3) phantom element, (4) spider, and (5) binnacle and gimbal rings. The binnacle and gimbal rings enclose and support the other four major components.

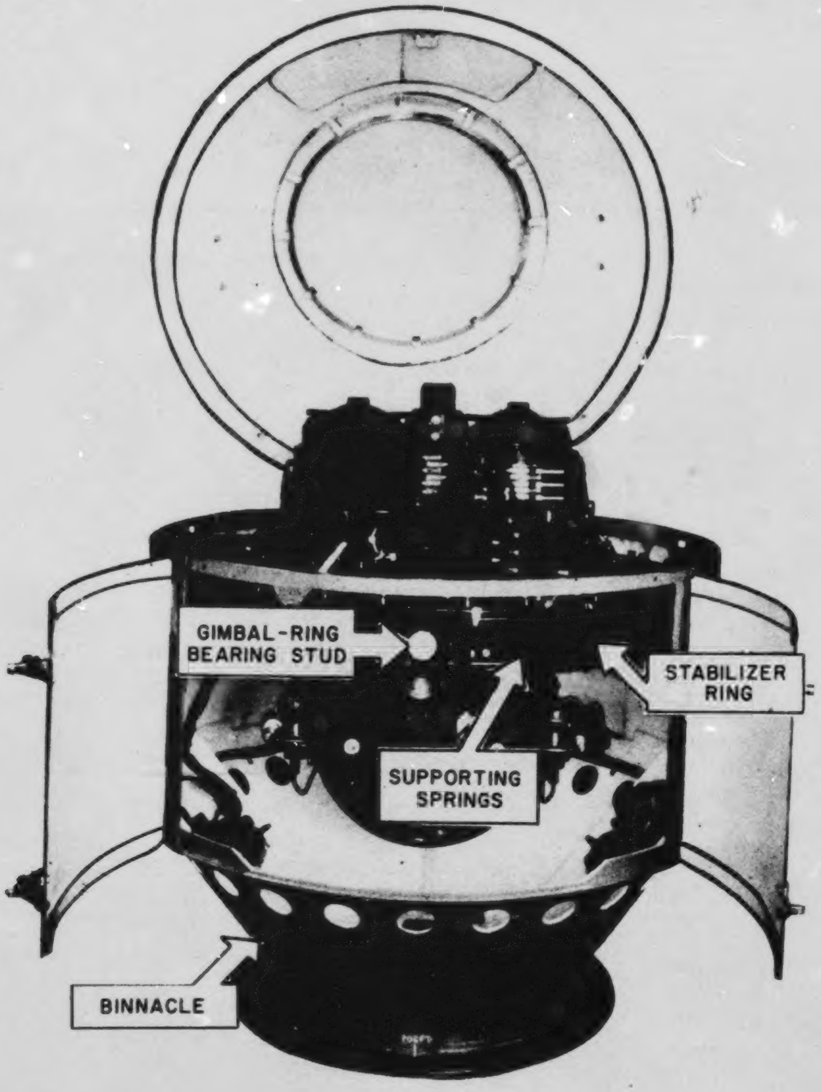
SENSITIVE ELEMENT

The sensitive element (fig. 6-11) is the north-seeking element of the master compass. It consists of the gyro unit, vertical ring, compensating weights, followup indicator (not shown) and suspension.

Gyro Unit

The gyro unit of the sensitive element provides rigidity of plane. The unit consists of the rotor and its case. The case is made airtight and the rotor operates in a vacuum (26 to 30 inches of mercury) to reduce the friction caused by air resistance.

A gyro case lock (fig. 6-11) prevents the tilting of the gyro case about its horizontal axis when the compass is not operating. This latch should be disengaged only when the rotor is


GIMBAL-RING BEARING STUD
STABILIZER RING
SUPPORTING SPRINGS
BINNACLE

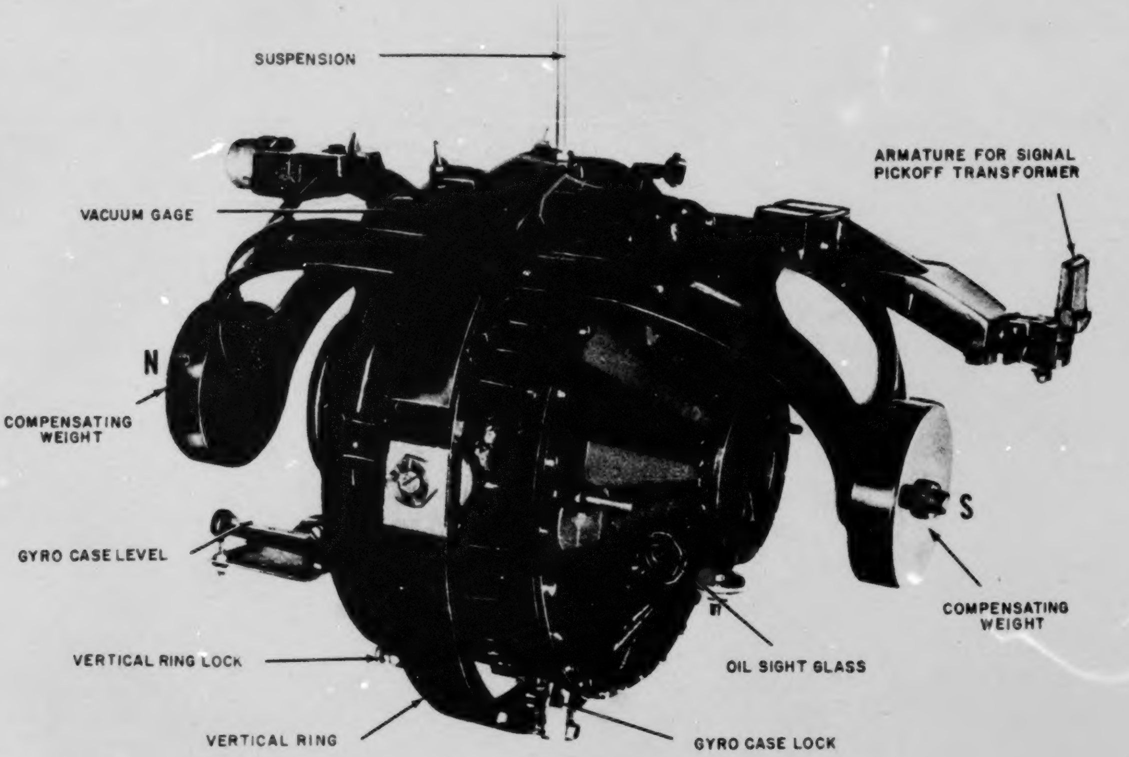
40.35

Figure 6-10.—Sperry Mk 11 Mod 6 gyrocompass showing binnacle and gimbal rings.

running at normal speed. It is located on the lower part of the south side of the vertical ring.

Vertical Ring

The vertical ring (fig. 6-11) is attached to a wire suspension from the head of the phantom element. The vertical ring is concentric with the phantom ring which surrounds the entire sensitive element. The phantom ring is kept in alignment with the ring, while the compass is in operation, by the action of the followup system, discussed later.


SUSPENSION
ARMATURE FOR SIGNAL PICKOFF TRANSFORMER
VACUUM GAGE
N
COMPENSATING WEIGHT
S
GYRO CASE LEVEL
COMPENSATING WEIGHT
VERTICAL RING LOCK
OIL SIGHT GLASS
VERTICAL RING
GYRO CASE LOCK

40.30

Figure 6-11.–Sperry Mk 11 Mod 6 sensitive element.

A vertical ring lock (fig. 6-11) keeps the vertical ring in line with the phantom ring when the compass is not operating. This lock prevents the wire suspension from acquiring a permanent set which would affect the settling point of the compass.

Compensating Weights

The compensating weights (fig. 6-11) are supported by two frames that are attached to the vertical ring. The frames project outward beyond each end of the rotor axle. The weights are mounted on studs. Positions of the weights can be adjusted in the direction of the axis of the gyro rotor. The function of the weights is to provide an even distribution of the weight of the gyrocompass about the vertical axis.

The armature of the signal pickoff or followup transformer is attached to an arm that protrudes horizontally from the upper part of the south compensating weight frame (fig. 6-11).

Suspension

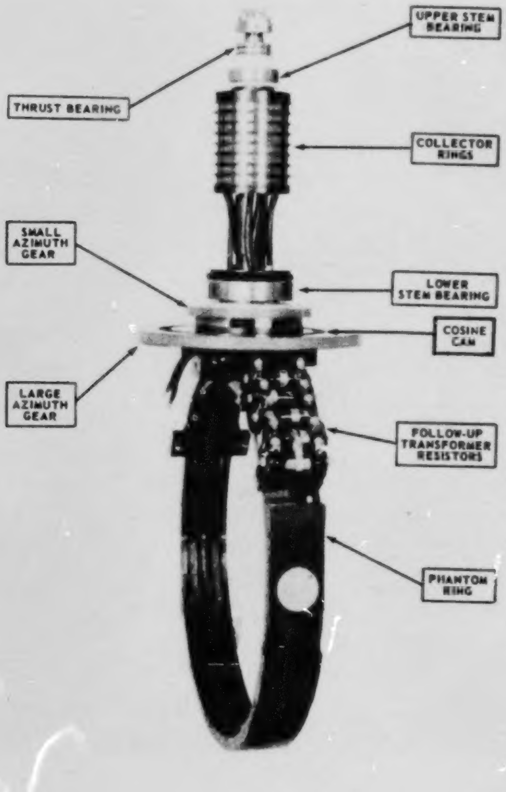
The suspension (fig. 6-11) suspends the entire sensitive element from the phantom element. It consists of a number of small steel wires secured at the upper end to the head of the phantom element and at the lower end to the vertical ring.

PHANTOM ELEMENT

The phantom element (fig. 6-12) is composed of a group of parts that acts to support the sensitive element. It consists essentially of a hollow cylindrical stem that projects radially from the phantom ring, which is mounted in the spider and extends below the central hub of the spider table. A means of attaching the top end of the suspension wire is provided at the top of the stem.

The phantom element has no north-seeking properties of its own. However, it does continuously indicate north. The action of the followup system makes the phantom element follow all movements of the sensitive element.

A thrust bearing on the top of the cylindrical stem (fig. 6-12) rests in the hub of the spider table and supports the weight of the phantom and sensitive elements.



40.33

Figure 6-12.—Sperry Mk 11 Mod 6 phantom element.

In addition to its function of support of the sensitive element, the phantom ring also carries bearings that support the mercury ballistic.

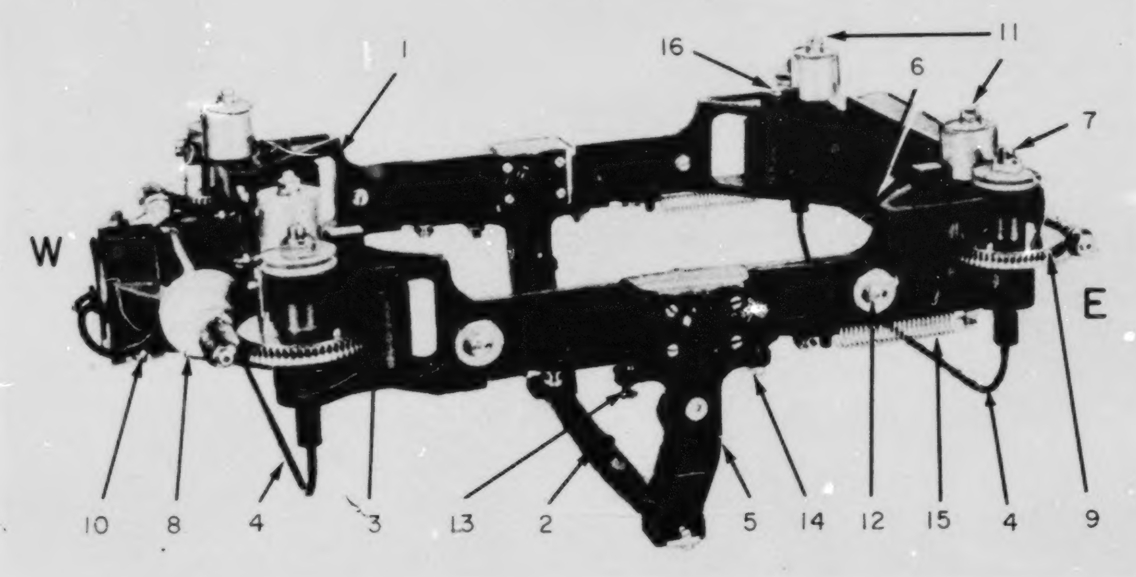
Collector rings are mounted on the cylindrical stem below the upper stem bearing to connect the various electrical circuits from the fixed to the moving parts of the compass.

MERCURY BALLISTIC

The mercury ballistic (fig. 6-13) is that group of parts which applies the gravity controlling force to the gyro unit and makes it north-seeking. It consists of a rigid frame supported on bearings in the phantom ring. These bearings are in line with the horizontal case bearings in the vertical ring so that the mercury ballistic is free to tilt about the east-west axis of the sensitive element.

The frame supports a mercury reservoir in each of its four corners. The N and S reservoirs on the east side of the compass are connected by a U-shaped tube, and the N and S reservoirs on the west side are similarly connected. The gravity controlling force of the mercury ballistic is applied to the bottom of the gyro case through an adjustable offset bearing stud (2) mounted on the ballistic connection arm (5).

The connection bearing is offset to the east from the vertical axis by a short distance to provide the damping adjustment. When it is desired to eliminate damping, a solenoid (damping eliminator magnet) is energized by an automatic damping eliminator switch (discussed later) that attracts a plunger which moves the pivoted connection arm until the connection bearing is in line with the vertical axis of the gyro. In addition, each mercury reservoir is offset from its supporting stem so that each reservoir can be rotated around its stem through an arc of approximately 110° to vary the lever arm of each tank. Thus, the period of an undamped oscillation of the gyrocompass is maintained constant in all latitudes by adjustment of the mercury reservoirs. This adjustment is referred to as the ballistic latitude adjustment.



1. MERCURY BALLISTIC FRAME
2. OFFSET CONNECTION BEARING STUD
3. MERCURY RESERVOIRS
4. MERCURY TUBE
5. CONNECTION ARM
6. MERCURY BALLISTIC SUPPORT STUD
7. MERCURY RESERVOIR SUPPORT STEM
8. LATITUDE SETTING THUMB WHEEL
9. LATITUDE SCALE
10. DAMPING ELIMINATOR MAGNET
11. NON-PENDULOUS BALANCING WEIGHTS
12. HORIZONTAL BALANCING WEIGHTS
13. NO-DAMPING ADJUSTMENT SCREW
14. DAMPING ADJUSTMENT
15. MAGNET LINK SPRING
16. LEVELING SCREW HOLES

40.32

Figure 6-13.–Sperry Mk 11 Mod 6 mercury ballistic.

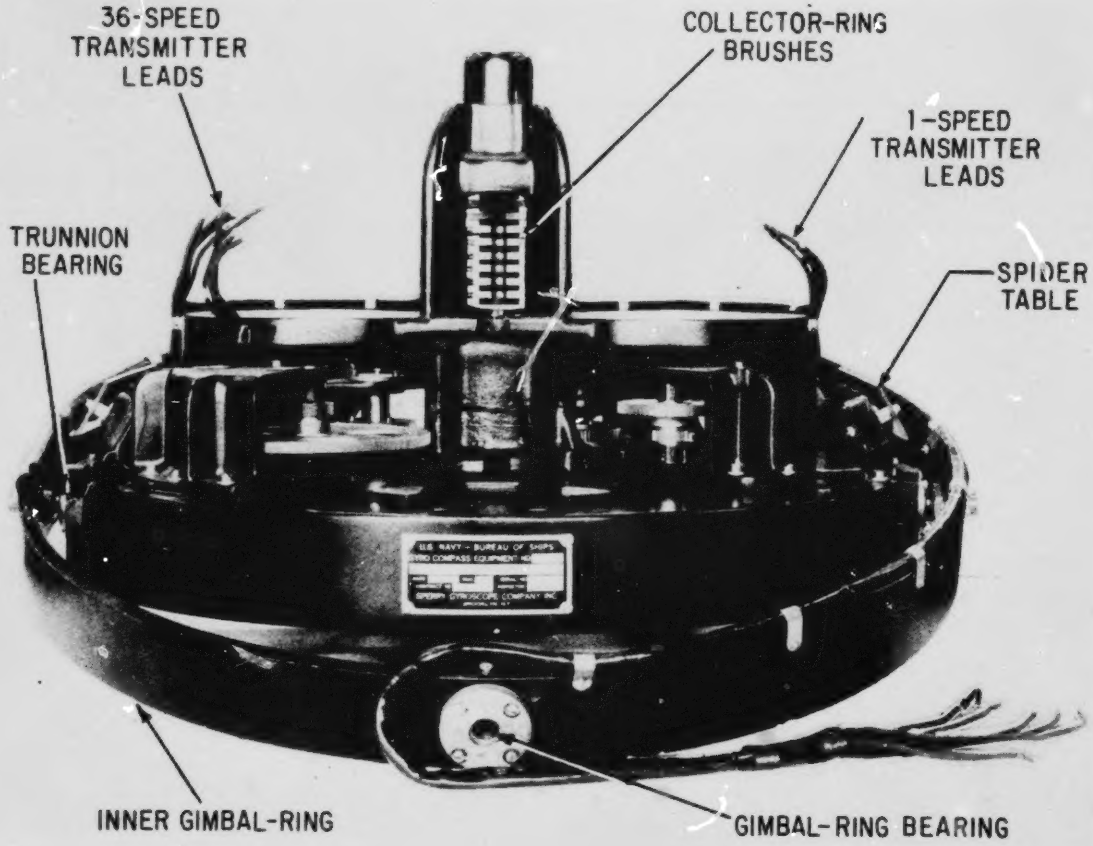
SPIDER

The spider (fig. 6-14) is a circular table of cast aluminum alloy. It is supported in the inner ring of the two rings that comprise the gimbal system. A boss in the center of the spider table supports the thrust bearing and the upper and lower stem bearings of the phantom element. Therefore, the entire inner, or moving, members of the compass are supported by the spider through the thrust bearing.

The azimuth followup motor and the automatic damping eliminator switch are mounted on the forward side of the spider table. The speed and latitude correction mechanism and the auxiliary latitude corrector are mounted on the after side of the table. The 36-speed synchro transmitter is located on the port side and the single-speed synchro transmitter is located on the starboard side of the table.

CONTROL AND ALARM SYSTEM

The Sperry Mk 11 Mod 6 gyrocompass control and alarm system (fig. 6-15) consists of a motor-generator, speed regulator, control panel, battery throwover panel, and bridge alarm indicator, with the necessary apparatus to operate and control the master compass.


36-SPEED TRANSMITTER LEADS
COLLECTOR-RING BRUSHES
1-SPEED TRANSMITTER LEADS
TRUNNION BEARING
SPIDER TABLE
INNER GIMBAL-RING
GIMBAL-RING BEARING

40.34

Figure 6-14.—Sperry Mk 11 Mod 6 spider.

The gyrocompass drive system consists of the primary and emergency sources of power. The primary power source is the ship's 3-phase, 120-volt, 60-Hz supply, and the emergency power source is the 24-volt battery supply.

Motor-Generator

Two separate motor-generator sets are provided with each complete Sperry gyrocompass equipment. Each set consists of an a.c. motor, a d.c. emergency motor, an a.c. generator, and a d.c. generator (fig. 6-15). The a.c. motor and the d.c. emergency motor are mounted on a common shaft in a single frame. The a.c. generator and the d.c. generator are also mounted on a common shaft in a single frame. The shafts of these two units are directly coupled together. Each motor-generator set is assembled as a complete unit and mounted on a single bedplate.

Compass Control Panel

The compass control panel is located at the upper left-hand section of the gyrocompass switchboard (fig. 6-16). The control panel controls and indicates the operating conditions of the master compass. The ship's 3-phase, 120-volt, 60-Hz power supply and the ship's single-phase, 120-volt, 60-Hz power supply are connected directly to terminals on the back of the compass control panel. The 3-phase, 120-volt, 60-Hz power supply is fed from these terminals on the control panel through the battery throwover relay on the battery throwover panel to the motor-generator transfer switch on the compass control panel. The switches and fuses for these power supplies are included on the IC switchboards.

Bridge Alarm Indicator

The bridge alarm indicator (fig. 6-17) is located in the pilot house. The indicator includes red, blue, and green indicator lamps, a damping-eliminator pushswitch and a starting pushswitch, all enclosed within a metal case provided for bulkhead mounting. An external alarm bell is located adjacent to this indicator.

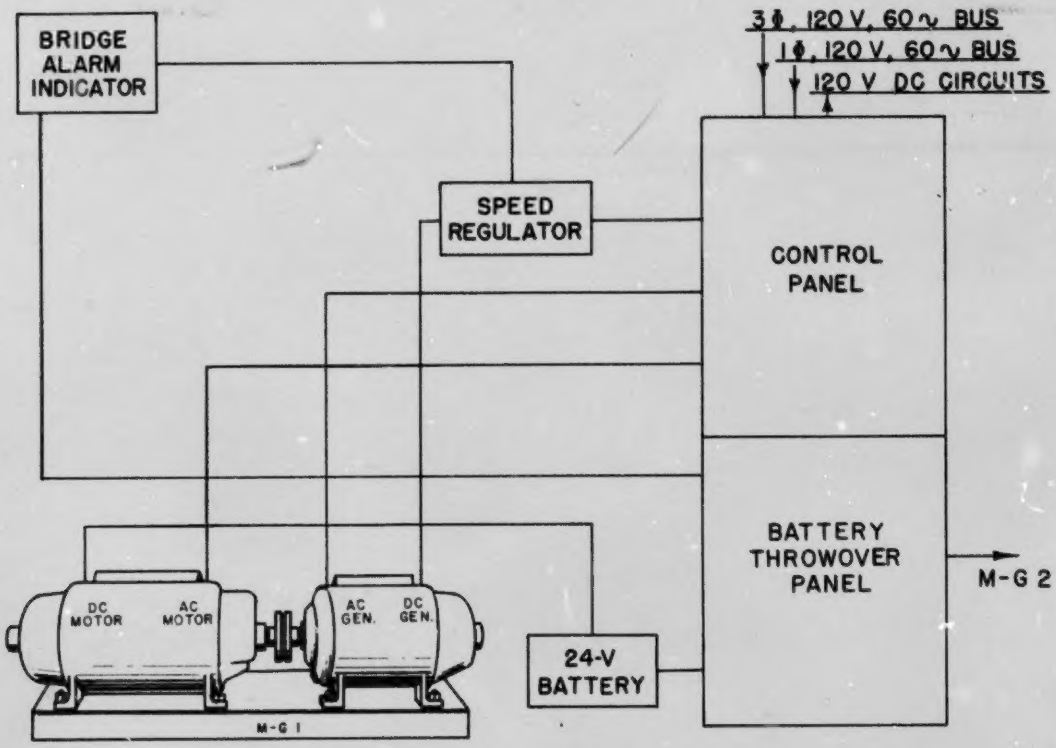
The red indicator lamp in the battery supply indicates operation of the compass equipment from the 24-volt battery supply.

The blue indicator lamp is in the damping-eliminator circuit as a warning whenever the damping-eliminator coil is energized.

The green indicator lamp in the ship's a.c. supply is lighted as long as the ship's supply is connected to the compass equipment.

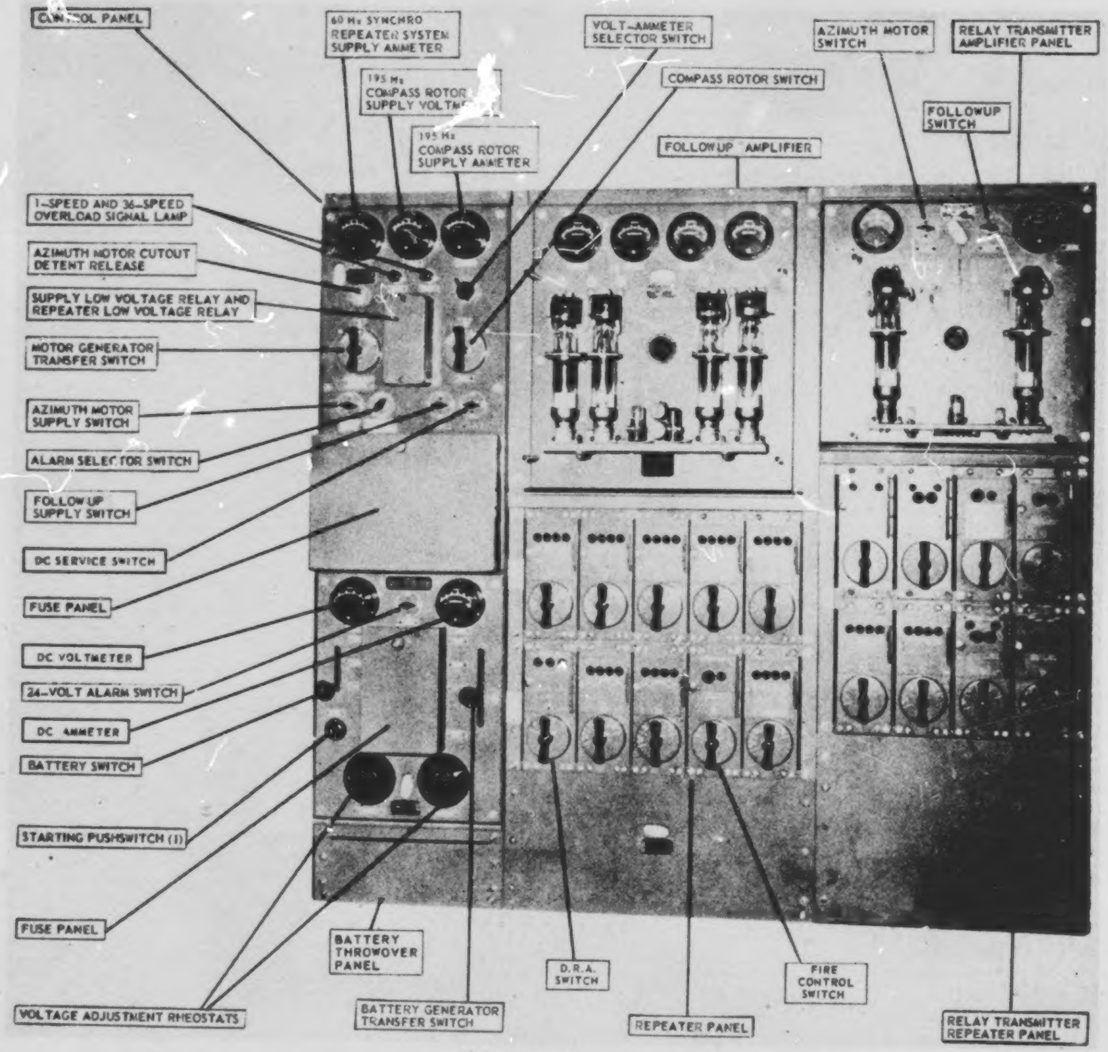
Each indicator lamp is provided with a series variable resistor to control the intensity of illumination.

The starting pushswitch is in parallel with the pushswitch on the battery throwover panel.



40.36

Figure 6-15.–Sperry Mk 11 Mod 6 gyrocompass control and alarm system.


CONTROL PANEL
60 Hz SYNCHRO REPEATER SYSTEM SUPPLY AMMETER
195 Hz COMPASS ROTOR SUPPLY VOLTMETER
195 Hz COMPASS ROTOR SUPPLY AMMETER
VOLT-AMMETER SELECTOR SWITCH
COMPASS ROTOR SWITCH
FOLLOWUP AMPLIFIER
AZIMUTH MOTOR SWITCH
RELAY TRANSMITTER AMPLIFIER PANEL
FOLLOWUP SWITCH
1-SPEED AND 36-SPEED OVERLOAD SIGNAL LAMP
AZIMUTH MOTOR CUTOUT DETENT RELEASE
SUPPLY LOW VOLTAGE RELAY AND REPEATER LOW VOLTAGE RELAY
MOTOR GENERATOR TRANSFER SWITCH
AZIMUTH MOTOR SUPPLY SWITCH
ALARM SELECTOR SWITCH
FOLLOW UP SUPPLY SWITCH
DC SERVICE SWITCH
FUSE PANEL
DC VOLTMETER
24-VOLT ALARM SWITCH
DC AMMETER
BATTERY SWITCH
STARTING PUSHSWITCH (1)
FUSE PANEL
VOLTAGE ADJUSTMENT RHEOSTATS
BATTERY THROWOVER PANEL
BATTERY GENERATOR TRANSFER SWITCH
D.R.A. SWITCH
REPEATER PANEL
FIRE CONTROL SWITCH
RELAY TRANSMITTER REPEATER PANEL

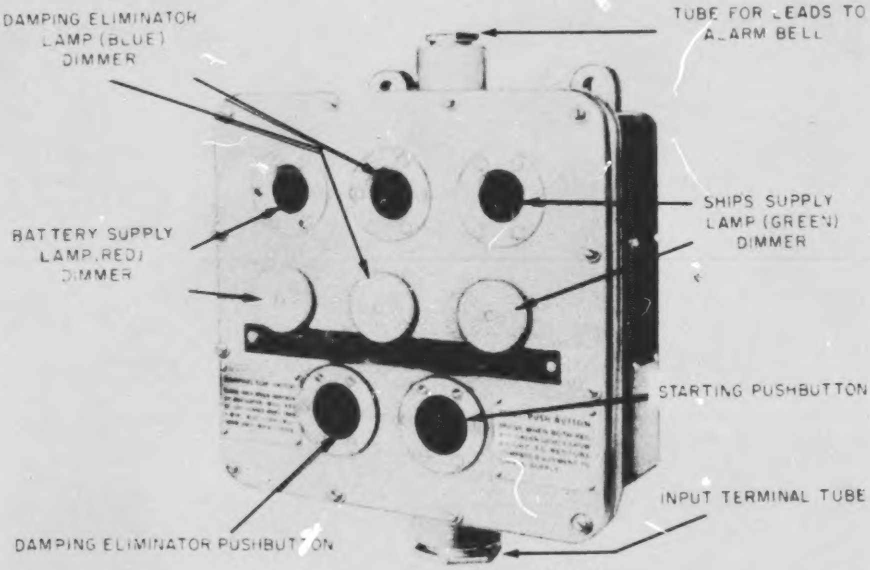
40.39

Figure 6-16.—Sperry Mk 11 Mod 6 gyrocompass switchboard.

The damping-eliminator pushswitch is in parallel with the automatic damping-eliminator switch on the master compass and may be manually operated to energize the damping-eliminator coil and thus remove damping.

FOLLOWUP SYSTEM

The followup system includes the followup mechanism, the followup transformer, the azimuth motor, and the followup panel. The system detects any misalignment between the


DAMPING ELIMINATOR LAMP (BLUE) DIMMER
TUBE FOR LEADS TO ALARM BELL
BATTERY SUPPLY LAMP (RED) DIMMER
SHIPS SUPPLY LAMP (GREEN) DIMMER
STARTING PUSHBUTTON
INPUT TERMINAL TUBE
DAMPING ELIMINATOR PUSHBUTTON

77.212

Figure 6-17.—Bridge alarm indicator.

phantom and sensitive elements and drives the phantom element in the proper direction to restore alignment. Any misalignment between the phantom and sensitive elements results in a signal voltage output from the followup transformer. The amount of misalignment determines the magnitude of this signal voltage, and the direction of misalignment determines its phase. The signal output from the followup transformer is amplified by a voltage amplifier and is used to control the output of a power amplifier which operates the azimuth motor. The azimuth motor, in driving the phantom element back into alignment with the sensitive element, also drives the single and 36-speed synchro transmitters and a lost-motion device through the azimuth followup gearing.

TRANSMISSION SYSTEM

The Sperry Mk 11 gyrocompass transmission system transmits the heading indicated by the master gyrocompass to a number of gyro repeaters, also called own ship's course (OSC) repeaters, located at various stations throughout the ship. The 1-speed and 36-speed synchro transmitters (driven by the azimuth followup motor) control the movement of the own ships course repeaters which indicate the readings of the master compass at the remote stations.

The transmission system also includes the transmitter overload relays, repeater panel, relay transmitter repeater panel, relay transmitter, relay transmitter amplifier panel, differential alarm relay, and repeater compasses.

Two similar transmitter overload relays, mounted on the back of the compass control panel, provide a visual alarm when an overload occurs in the transmitter circuits. One relay is connected in the 1-speed transmitter circuit, and the other relay is connected in the 36-speed transmitter circuits.

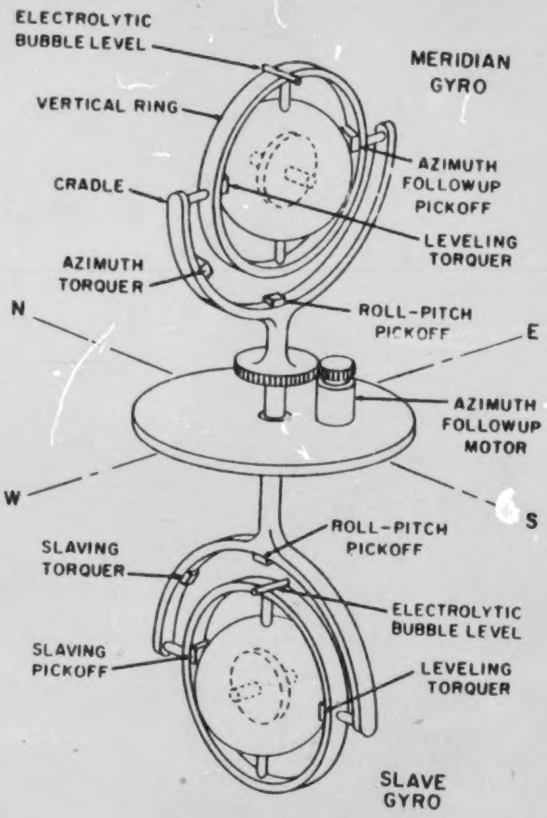
The repeater panel (fig. 6-16) is located below the followup panel. It comprises an assembly of rotary switches, and auxiliary equipment. Each switch, with its associated fuses and overload indicating devices, is assembled as a unit and can be withdrawn from the front of the panel for inspection and repair.

To actuate a number of repeater compasses without imposing this load directly on the compass transmitters, an intermediate instrument (relay transmitter) is used. The relay transmitter (not shown) consists of a 1-speed and a 36-speed synchro control transformer (CT), a commutator transmitter, a followup motor, and a reactor, all enclosed within a metal case provided for bulkhead mounting.

SPERRY MK 19 GYROCOMPASS

The Mk 19 gyrocompass is a navigational and fire control instrument with design features based on unusual requirements. In addition to own ship's heading data, it accurately measures and transmits angles of roll and pitch. These features distinguish the Mk 19 from all other shipboard gyrocompasses that preceded it.

Design of the compass is based on the principle that two properly controlled horizontal gyros used together can furnish a stable reference for the measurement of ship's heading, roll, and pitch. Briefly, the basic unit consists of two gyros placed with their spin axes as shown in figure 6-18. The top gyro is a conventional gyrocompass and is referred to as the north-seeking, or meridian gyro. Its spin axis is directed along a north-south line and it furnishes indications of ship's heading, roll (on 090° and 270° course), and pitch (on 000° and 180° course). The lower gyro is positioned with its spin axis slaved to the meridian gyro along an east-west line. It is referred to as the slave gyro and furnishes indications of roll on north-south courses, and pitch on east-west courses.

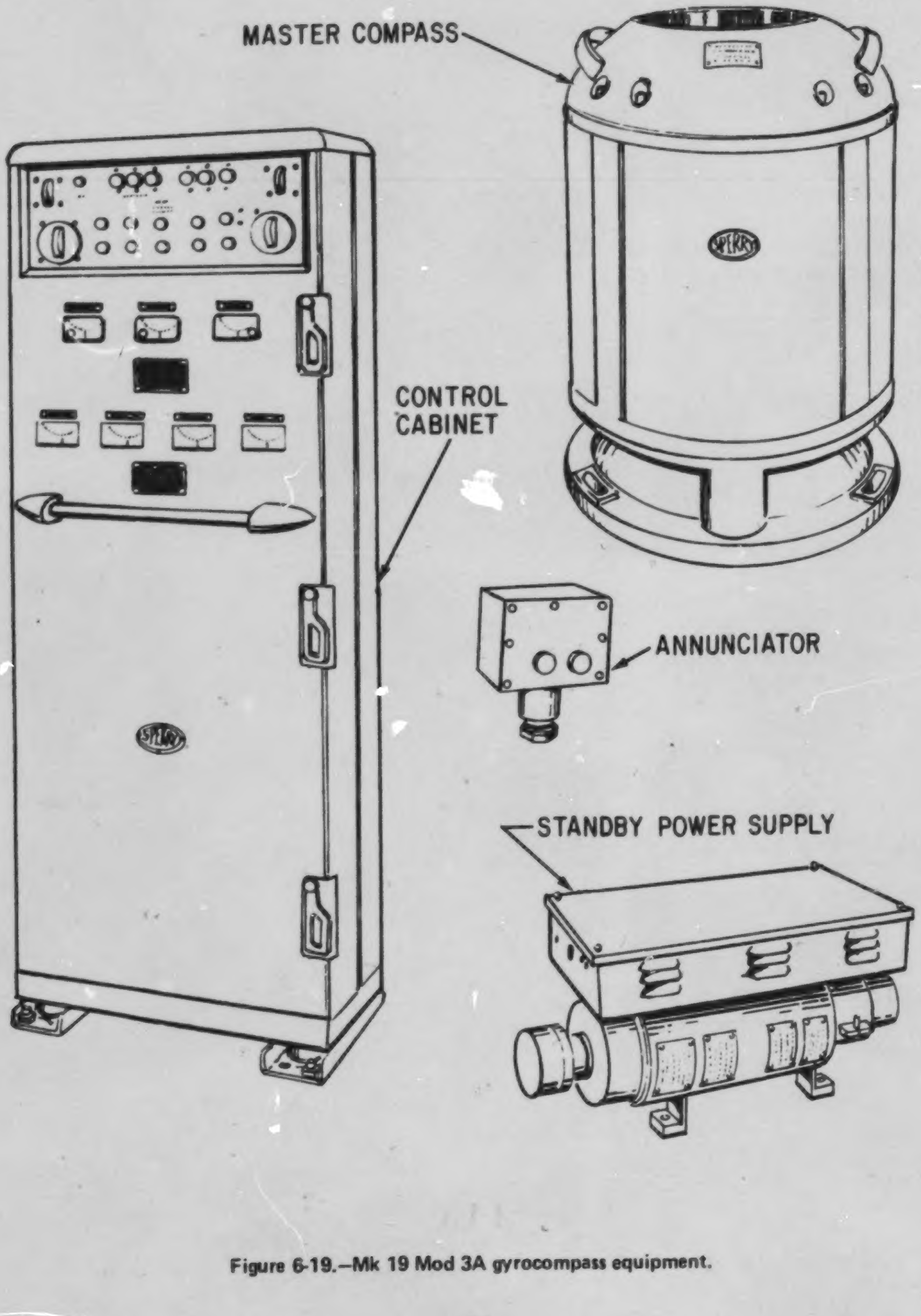


27.168

Figure 6-18.—Simplified diagram of the Mk 19 gyrocompass element.

The Mk 19 gyrocompass has an electronic control system that makes it seek and indicate true north as well as the zenith. A gravity reference system detects gyro tilt, and torques are applied electromagnetically to give the meridian gyro the desired period and damping. Further, signals are generated by the compass to stabilize the entire sensitive element in roll and pitch, thereby furnishing an indication of the zenith in terms of roll and pitch data.

Both the meridian and slave gyros are enclosed in hermetically sealed spheres, these spheres are suspended in oil. The compass is compensated for northerly and easterly speed and acceleration, earth rate, constant torques, and followup errors. The system consists of four major components: the master compass, control cabinet, compass failure annunciator, and standby supply (fig. 6-19). The Mk 19 Mod 3B, 3C, and 3D employ a static power supply (not shown) in place of the m-g set. In all cases the gyrocompasses are installed with a no-break


MASTER COMPASS
CONTROL CABINET
ANNUNCIATOR
STANDBY POWER SUPPLY
SPERRY
SPERRY

27.169

Figure 6-19.–Mk 19 Mod 3A gyrocompass equipment.

supply from a battery source for use in the event of a normal supply failure.

MASTER COMPASS

The master compass (fig. 6-19) is approximately 3 feet high and weighs approximately 685 pounds. Its two major portions are the compass element and the supporting element (fig. 6-20).

Compass Element

The compass element includes the sensitive element (meridian and slave gyros), the gimbal, and the phantom assembly. The phantom assembly includes the azimuth phantom, which defines the meridian, and the roll and pitch phantom, which defines the zenith.

Supporting Element

The supporting element includes the frame and binnacle. The compass elements are gimbaled in the binnacle by a conventional gimbaling system, with ±60 degrees of freedom about the roll axis and ±40 degrees of freedom about the pitch axis.

The meridian and slave gyros are similar in construction with the exception that the gravity reference is inverted in the slave gyro which necessitates minor changes in wiring. The two gyro assemblies are mounted on the inner ring of the phantom assembly—the meridian gyro is on top, and the slave gyro is upside down below it. The gyro motors are 2-pole, 115-volt, 3-phase, 400-Hz squirrel-cage induction motors. Viewed from the south, the meridian gyro rotates approximately 23,600 rpm clockwise, and, viewed from the west, the slave gyro rotates at the same speed clockwise.

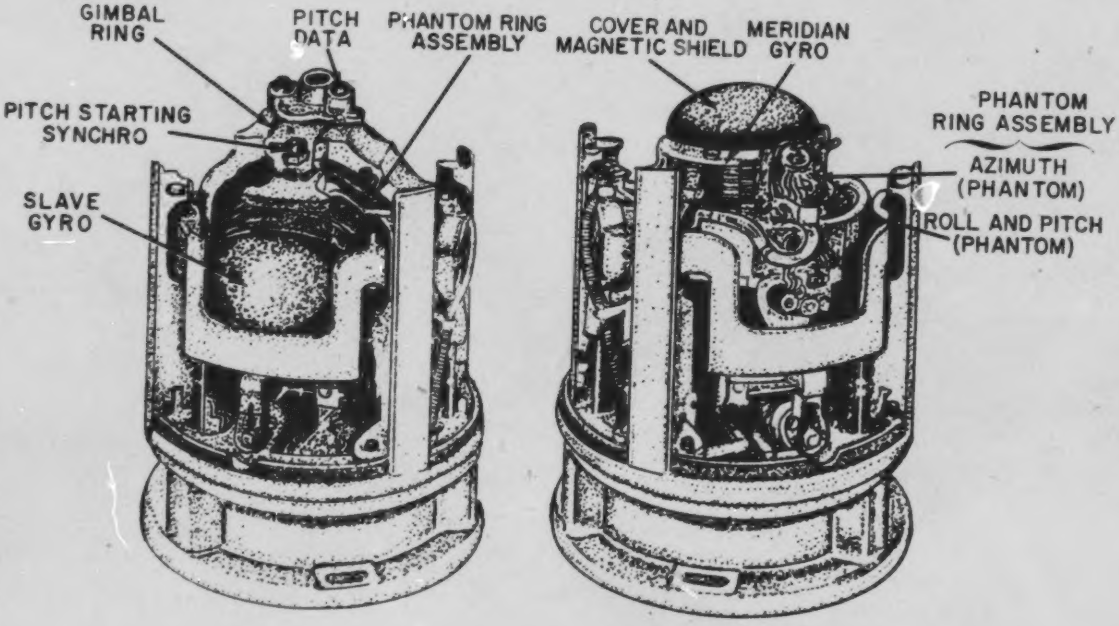

GIMBAL RING
PITCH DATA
PHANTOM RING ASSEMBLY
COVER AND MAGNETIC SHIELD
MERIDIAN GYRO
PITCH STARTING SYNCHRO
SLAVE GYRO
PHANTOM RING ASSEMBLY
AZIMUTH (PHANTOM)
ROLL AND PITCH (PHANTOM)

Figure 6-20.—Two views of master compass showing compass element and supporting element. 27.170

The azimuth phantom follows the azimuth motion of the meridian gyro, and 1- and 36-speed heading data are transmitted by the azimuth servo and synchro assemblies mounted on the phantom assembly. The roll and pitch phantom is stabilized in roll and pitch, and 2- and 36-speed roll and pitch data are transmitted by the roll and pitch servo and synchro assemblies mounted on the frame and binnacle.

CONTROL CABINET

The control cabinet (fig. 6-19) contains the d.c. power supply, analog computers, amplifiers, and other assemblies required for operating and indicating the condition of the gyrocompass system. The cabinet is composed of the control panel, computer indicator panel, computer control assembly, system control assembly, followup amplifiers, the d.c. power supply, and a voltage regulator.

Control Panel

The control panel, located at the top of the control cabinet, contains all the switches, alarm lamps, and indicator fuses required for operating the system. Only the controls required for normal operation of the system are accessible when the control cabinet is closed. These controls are on a recessed panel to avoid injury to personnel, damage to the controls, or accidental change of setting.

Computer Indicator Panel

Below the control panel, inside the cabinet, are seven computer assemblies for computing data for the system. The computer indicators are viewed through seven flush windows in the front of the cabinet. Each of these assemblies are discussed later with the control system in which it is used.

Computer Control Assembly

To minimize the number of different kinds of amplifiers used in the system, two types of standard plug-in computer amplifiers are used in 13 applications. As the circuits in which the amplifiers are used vary, other components peculiar to a single circuit must be used. For this reason a T-shaped panel, the computer control assembly, is located inside the control cabinet. This panel provides a junction box into which the amplifiers may be plugged and serves as a chassis for the various components required to match the standard amplifiers to the particular circuits concerned. The computer control assembly houses eleven type 1 and two type 2 general-purpose computer amplifiers and contains all the components required to operate the various computer and torquer circuits, other than those contained in the mechanical assemblies or in the master compass.

System Control Assembly

The system control assembly is mounted at the top of the rear section of the control cabinet and includes switches, relays time delay circuits, and auxiliary devices for cycling the events automatically, as required for starting and operating the compass system. These components operate in conjunction with the switches, indicators, and relays on the control panel, and elsewhere in the system, to perform starting and control functions.

Followup Amplifiers

Mounted below the system control assembly are the roll, pitch, and azimuth followup amplifiers. The three followup amplifiers are identical and interchangeable.

D.C. Power Supply

Below the followup amplifiers is the d.c. power supply unit containing the power supply components (metallic rectifiers, filters and so forth), a monitoring meter, and associated selector switch. The unit operates from the 115-volt, 400-Hz, 3-phase supply and furnishes all d.c. voltages required to operate the various amplifiers and relays in the system.

Voltage Regulator

Since a supply voltage fluctuation as low as 2 volts can cause compass errors, a voltage regulator was developed for the Mk 19 system. This regulator is installed in the bottom of the control cabinet and provides an output of 115 volts, 400-Hz regulated to within ±0.75 volt for an input of 115 volts ±7 volts.

An alarm indicator lamp indicates servo unbalance, tube heater failure, and excessive input voltage.

COMPASS FAILURE ANNUNCIATOR

The compass failure annunciator (fig. 6-19) is a remote visual indicator. Associated with the annunciator is usually a Navy standard type alarm bell. The alarm bell and annunciator are actuated by the alarm control system to give both a visual and audible indication of system failure.

STANDBY SUPPLY

The Sperry Mk 19 Mod 3 and 3A standby power supply (fig. 6-19) is a motor-generator set which provides emergency power to the compass system for a short time when the ship's power supply fails. Under normal operation the a.c. section operates as a 115-volt, 400-Hz, 3-phase synchronous motor, to drive a 120-volt compound-wound d.c. generator, which charges a bank of twenty 6-volt storage batteries. If the ship's 400-Hz supply fails or falls below 102 volts, the ship's line is disconnected automatically and the 120-volt d.c. generator is driven as a motor by the storage batteries. The a.c. section now operates as a 115-volt, 400-Hz, 3-phase generator supplying the compass system.

The standby supply for the Sperry Mk 19 Mod 3B and 3C gyrocompass is a static unit (not shown) with no moving parts other than relays. Transistors and magnetic amplifiers make the unit adaptable for providing 115-volt, 3-phase, 400-Hz power to the gyro system from either the ship's 115-volt, 3-phase, 400-Hz supply or from a 120-volt battery supply.

GYROCOMPASS CONTROLS

All controls for the Mk 19 gyrocompass system (fig. 6-21) are contained in four major systems—the meridian gyro control system, slave gyro control system, the azimuth followup system, and the roll and pitch followup system.

MERIDIAN GYRO CONTROL SYSTEM

The meridian gyro control system which makes the Mk 19 north seeking and indicating includes the gravity reference system, the azimuth control system, and the leveling control system.

Meridian Gyro Gravity Reference System

The gravity reference system (fig. 6-21A) consists of the meridian gyro gravity reference (the electrolytic bubble level and excitation transformer), the north-south acceleration computer, a mixer and its associated network.

The electrolytic bubble level is mounted on the meridian gyro vertical ring so that it is parallel to the gyro axle. Its operation was explained earlier in this chapter. When the level is tilted from the horizontal, an output signal voltage proportional in magnitude to the amount of tilt will be produced and the phase or instantaneous polarity of the voltage will be dependent on the direction of tilt.

The tilt signal from the electrolytic bubble level is fed into the mixer (fig. 6-21A) which contains a stepup transformer and a cathode follower. The tilt signal is mixed with the north-south acceleration signal (a compensation signal to be discussed later), and the compensated tilt signal is fed into a network of resistors, potentiometers, and relay contacts. The network has three output signals: the meridian control signal to the azimuth control system, the damping signal to the leveling control system, and the compensated tilt signal to the meridian gyro constant torque compensation system.

Meridian Gyro Azimuth Control System

The azimuth control system (fig. 6-21B) consists of a mixer, an azimuth torquer

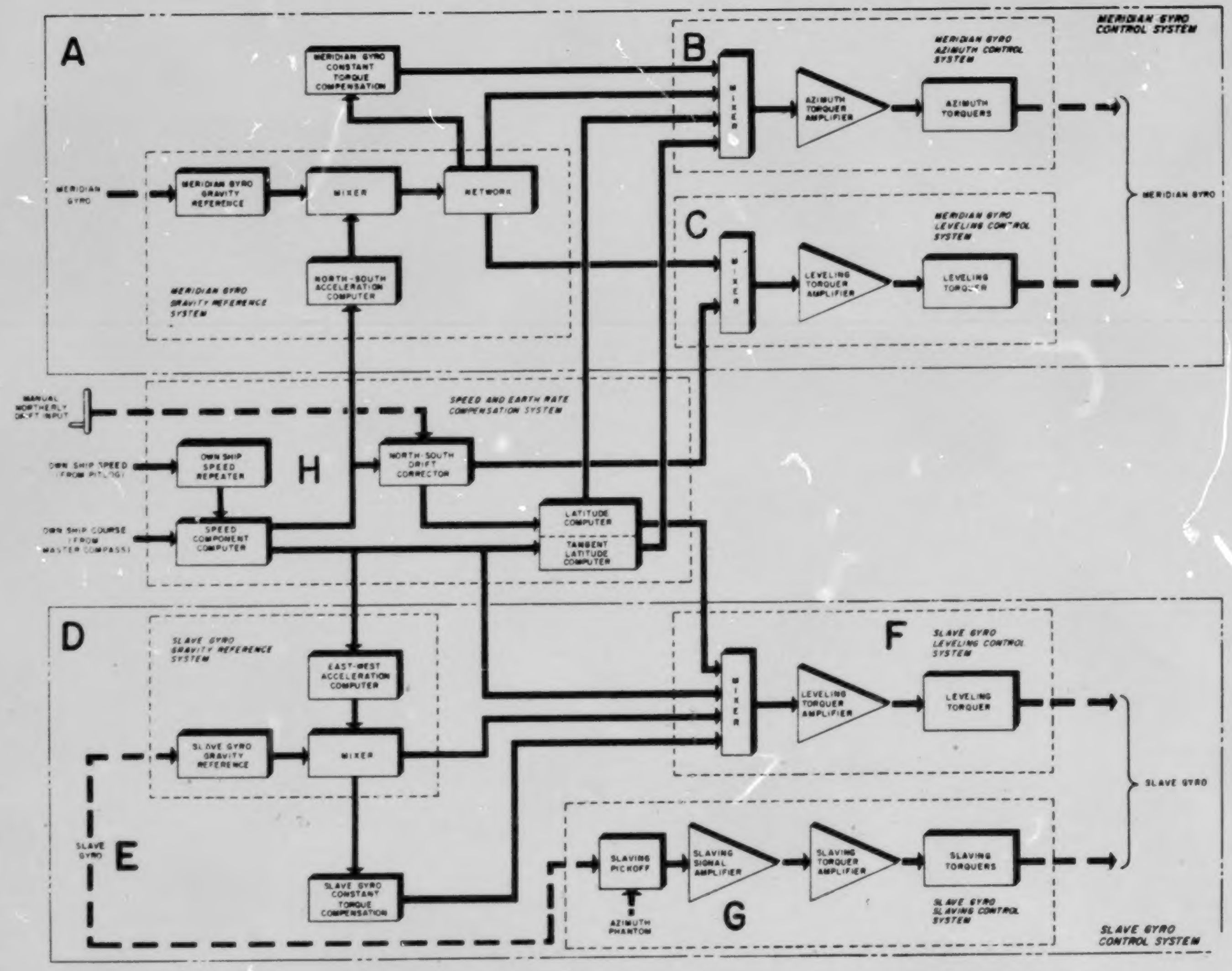
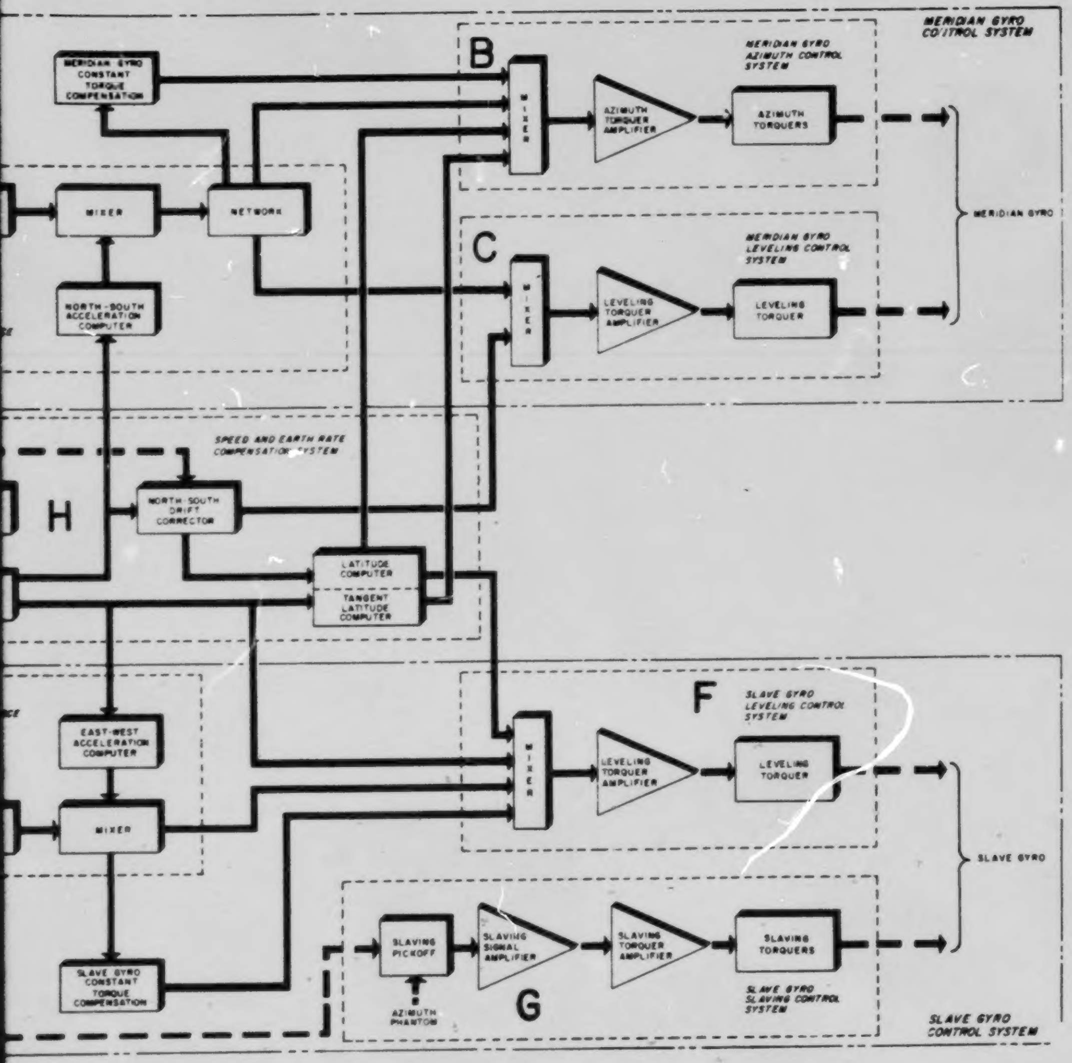

A
MERIDIAN GYRO CONSTANT TORQUE COMPENSATION
MERIDIAN GYRO
MERIDIAN GYRO GRAVITY REFERENCE
MIXER
NETWORK
NORTH-SOUTH ACCELERATION COMPUTER
MERIDIAN GYRO GRAVITY REFERENCE SYSTEM
MERIDIAN GYRO CONTROL SYSTEM
B
MIXER
AZIMUTH TORQUER AMPLIFIER
AZIMUTH TORQUERS
MERIDIAN GYRO AZIMUTH CONTROL SYSTEM
C
MIXER
LEVELING TORQUER AMPLIFIER
LEVELING TORQUER
MERIDIAN GYRO LEVELING CONTROL SYSTEM
MERIDIAN GYRO
MANUAL NORTHERLY DRIFT INPUT
SPEED AND EARTH RATE COMPENSATION SYSTEM
OWN SHIP SPEED (FROM PITLOG)
OWN SHIP SPEED REPEATER
H
NORTH-SOUTH DRIFT CORRECTOR
OWN SHIP COURSE (FROM MASTER COMPASS)
SPEED COMPONENT COMPUTER
LATITUDE COMPUTER
TANGENT LATITUDE COMPUTER
D
SLAVE GYRO GRAVITY REFERENCE SYSTEM
EAST-WEST ACCELERATION COMPUTER
SLAVE GYRO GRAVITY REFERENCE
MIXER
SLAVE GYRO
E
SLAVE GYRO CONSTANT TORQUE COMPENSATION
F
SLAVE GYRO LEVELING CONTROL SYSTEM
MIXER
LEVELING TORQUER AMPLIFIER
LEVELING TORQUER
SLAVE GYRO
SLAVING PICKOFF
AZIMUTH PHANTOM
SLAVING SIGNAL AMPLIFIER
SLAVING TORQUER AMPLIFIER
SLAVING TORQUERS
G
SLAVE GYRO SLAVING CONTROL SYSTEM
SLAVE GYRO CONTROL SYSTEM

Figure 6-21.--Block diagram of compass control system, of the Mk 19 gyrocompass.


MERIDIAN GYRO CONTROL SYSTEM
MERIDIAN GYRO CONSTANT TORQUE COMPENSATION
B
MIXER
AZIMUTH TORQUER AMPLIFIER
AZIMUTH TORQUERS
MERIDIAN GYRO AZIMUTH CONTROL SYSTEM
MIXER
NETWORK
NORTH-SOUTH ACCELERATION COMPUTER
C
MIXER
LEVELING TORQUER AMPLIFIER
LEVELING TORQUER
MERIDIAN GYRO LEVELING CONTROL SYSTEM
MERIDIAN GYRO
SPEED AND EARTH RATE COMPENSATION SYSTEM
H
NORTH-SOUTH DRIFT CORRECTOR
LATITUDE COMPUTER
TANGENT LATITUDE COMPUTER
EAST-WEST ACCELERATION COMPUTER
MIXER
SLAVE GYRO CONSTANT TORQUE COMPENSATION
F
SLAVE GYRO LEVELING CONTROL SYSTEM
MIXER
LEVELING TORQUER AMPLIFIER
LEVELING TORQUER
SLAVE GYRO
SLAVING PICKOFF
AZIMUTH PHANTOM
SLAVING SIGNAL AMPLIFIER
SLAVING TORQUER AMPLIFIER
SLAVING TORQUERS
G
SLAVE GYRO SLAVING CONTROL SYSTEM
SLAVE GYRO CONTROL SYSTEM

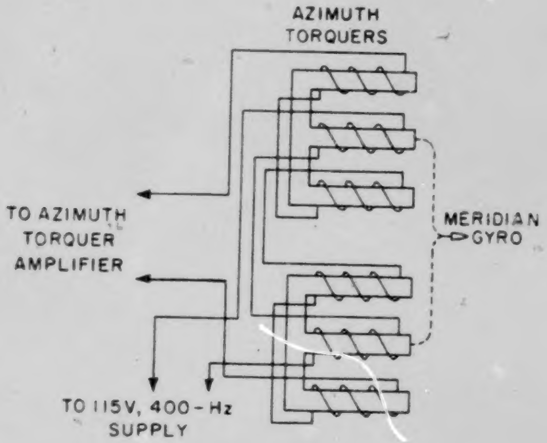
27.175

ure 6-21.--Block diagram of compass control system, of the Mk 19 gyrocompass.

amplifier, and two azimuth torquers. The mixer contains a stepup transformer, potentiometers and resistors. The azimuth torquer amplifier is a general-purpose type 1 computer amplifier, which contains two double-purpose triodes. The input stage uses one-half of one tube; the other half is used in the compass alarm circuit. The output stage uses both halves of its tube in a push-pull circuit. The mixer input signals are the meridian control signal from the gravity reference system, an east-west speed signal, a constant torque signal, and a vertical earth rate compensation signal. The azimuth torquer amplifier output is fed to the control fields of the two azimuth torquers which apply torque about the horizontal axis to precess the meridian gyro toward the meridian.

The azimuth torquers are the output elements of the azimuth control system which actually produce the torques applied to the gyro. The torquers are located opposite each other on the cradle (fig. 6-18) and are electrically connected to act together to produce the torque.

Each torquer (fig. 6-22) consists of an open-E rack structure of soft-iron laminations upon which are wound a control field (2 outer legs) and a reference field (center leg) displaced 90° to form a 2-phase induction motor field. These coils are excited from the output of the azimuth control amplifier and the 400-Hz supply.



27.341

Figure 6-22.—Azimuth torquers simplified schematic diagram.

The output voltage of the amplifier and the reference field voltage are 90 electrical degrees out-of-phase. When the torquer windings are energized, a moving field is set up in the air gap. This field cuts the vertical ring and induces currents in it. This action develops a torque that tends to drag the vertical ring along with the moving field.

The magnitude of the torque is proportional to the signal fed to the control winding (output of the amplifier). The direction of the torque depends on the phasing of the control-field voltage which may lead or lag the fixed-field voltage by 90 electrical degrees.

Meridian Gyro Leveling Control System

The meridian gyro leveling control system (fig. 6-21C) consists of a mixer (stepup transformer, potentiometer, and resistors), the leveling control amplifier (another type 1 computer amplifier), and the leveling torquer. The input signals to the mixer are the damping signal from the gravity reference system and the north-south speed plus the drift compensation signal. The amplifier output supplies the leveling torquer control field, which produces the torque to level the meridian gyro.

SLAVE GYRO CONTROL SYSTEM

The slave gyro control system (fig. 6-21D) consists of the slave gyro gravity reference system, leveling control system, and slaving control system.

Slave Gyro Gravity Reference System

The slave gyro gravity reference system (fig. 6-21D) is similar to the meridian gyro gravity reference system. It consists of a gravity reference, a mixer and its network, and the east-west acceleration computer. The output of the system is the slave gyro amplified and compensated tilt signal, which is fed to the slave gyro constant torque compensation system (fig. 6-21E) and the slave gyro leveling control system (fig. 6-21F).

Slave Gyro Leveling Control System

The slave gyro leveling control system (fig. 6-21F) consists of a mixer, a leveling torquer amplifier, and a leveling torquer. The input signals to the mixer are the compensated tilt signal from the slave gyro gravity reference system, horizontal earth rate from the latitude computer, east-west speed from the speed component computer, and constant torque compensation signals from the slave gyro constant torque compensation unit. The leveling torquer amplifier and leveling torquer are duplicates of those used in the meridian gyro leveling control system. The output of the leveling torquer amplifier to the leveling torquer control field is the slave gyro leveling control signal.

Slave Gyro Slaving Control System

The slaving control system (fig. 6-21G) detects any misalignment between the azimuth phantom and the slave gyro, and slaves the gyro to its proper east-west position. The system consists of the slaving pickoff, slaving signal amplifier, slaving torquer amplifier and two slaving torquers. The slaving pickoff is an E-core transformer mounted on the vertical ring. The armature of the pickoff is cemented to the gyrosphere. Thus, a misalignment signal between the azimuth phantom and the slave gyro is obtained from the pickoff. This signal is fed into the slaving signal amplifier which contains a stepup transformer and cathode follower. The output of the slaving signal amplifier is the slaving signal, and it is fed to the slaving torquer amplifier, a type I computer amplifier. The output of the slaving torquer amplifier is the slaving control signal, and it is fed to the slaving torquer control fields.

The slaving torquers are duplicates of the azimuth torquers, and operate in the same manner. They produce the torque about the slave gyro horizontal axis, which causes precession about the vertical axis, to realign the slave gyro with the azimuth phantom.

COMPENSATION SIGNALS

The compensation signals in the Mk 19 gyrocompass system serve to counteract or compensate for certain effects that would otherwise produce azimuth or leveling errors in the master compass.

The effects may be classified as ship effects, which include speed, course, and acceleration earth effects, which include horizontal and vertical earth rate; and constant torque effects, which may be caused by mechanical unbalance of the master compass; or any other mechanical defects that would cause the compass to settle with a tilt.

Northerly or southerly ship speed produces a gyrocompass error due to gyro tilt as the ship follows the curvature of the earth. The rate of this gyro tilt is proportional to the product of ship's speed (S), and the cosine of own ship's course (C). Easterly speed, however, produces an error equal to the product of ship's speed (S), and the sine of own ship's course (C). Easterly or westerly speed does not cause the meridian gyro to tilt. However, as the slave gyro is aligned east-west, it is affected by easterly or westerly speed in the same manner that northerly or southerly speed affects the meridian gyro. The Mk 19 compass is compensated for speed errors by applying a compensation signal equal to S cos C to the meridian gyro leveling control system and a signal equal to S sine C to the slave gyro leveling control system. Thus, both gyros are maintained in a level position for any speed or course. These signals are obtained from the own-ship speed repeater and speed component computer shown in the block diagram (fig. 6-21H).

As the ship's heading and course may differ due to north-south drift, the north-south speed signal is compensated for drift by a manual corrector located on the front of the control cabinet. This drift setting is made by the compass operator after he obtains the necessary information from the ship's navigator.

If the ship accelerates in speed, the inertia will displace the electrolyte in the electrolytic bubble level. Deceleration will cause a displacement in the opposite direction. As a result, tilt signals will be produced even though there is no gyro tilt, and compass errors will result if not compensated for.

Acceleration compensation is obtained for the meridian gyro by the north-south acceleration computer, and for the slave gyro by the east-west acceleration computer.

The effect of vertical earth rate on the meridian gyro is proportional to the product of earth rate at the equator and the sine of the ship's latitude. The effect of horizontal earth rate on the slave gyro is proportional to the product of the earth rate at the equator and the cosine of the ship's latitude. Since the effect of vertical earth rate is caused by the speed of the earth's rotation about its north-south axis, a ship traveling in an easterly or westerly direction will either add to or subtract from the earth's rotation. This apparent change in the speed of the earth's rotation will, in effect, produce a comparable change in vertical earth rate. This change, which is the meridian gyro east-west speed error, is proportional to the product of the ship's east-west speed and the tangent of the ship's latitude.

To compensate for these effects on the meridian gyro, we need a compensating signal voltage proportional to the product of earth rate at the equator and the sine of the ship's latitude, plus a compensating signal voltage proportional to the product of east-west speed and the tangent of the ship's latitude.

To compensate the slave gyro for the effect of horizontal earth rate, we need a compensating signal voltage proportional to the product of earth rate and the cosine of the ship's latitude. These compensating signals are obtained from the latitude and tangent latitude computers (fig. 6-21H).

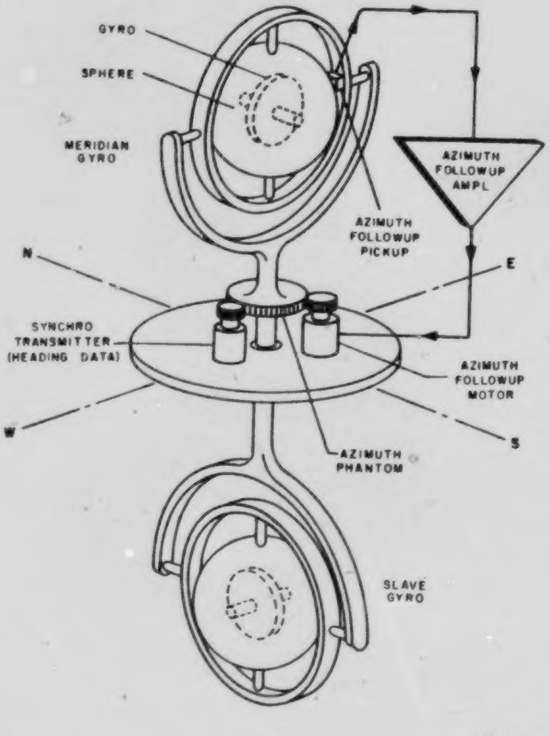
Because of wear it is not possible to keep the gyros perfectly balanced at all times. Therefore, a constant torque compensation system is provided for both meridian and slave gyros.

If the average signal from the electrolytic bubble level, or accelerometer, is not zero (such as caused by mechanical unbalance of the compass), the constant torque compensation system will produce an output signal voltage of opposite phase to (and thus tend to cancel) the tilt signal caused by the unbalance.

AZIMUTH FOLLOWUP SYSTEM

The azimuth followup system functions to indicate ship's course. In the previous paragraphs we have shown how the meridian gyro control system and the slave gyro control system function to maintain the meridian gyro north and south.

When the ship changes course or the gyro is settling out, the azimuth followup system (fig. 6-23) detects the misalignment between the vertical ring and gyrosphere and drives the



27.180

Figure 6-23.—Simplified diagram of azimuth followup system.

azimuth phantom (and therefore the vertical ring) back into alignment with the gyrosphere.

An azimuth pickoff, consisting of an E-core transformer mounted on the vertical ring and an armature cemented to the gyrosphere, furnishes the misalignment signal to the followup amplifier in the conventional manner. The followup motor, driven by the azimuth followup amplifier output, drives the azimuth phantom, restoring the azimuth pickoff to its neutral position and positioning, through gearing, the 1- and 36-speed heading data synchro transmitters. The followup motor also positions the rotor of the roll-pitch resolver (not shown in figure 6-23) to a position corresponding to the ship's heading.

The azimuth followup amplifier consists of a preamplifier stage, a demodulator stage with displacement and rate signal networks, and a magnetic amplifier output stage. Associated with the amplifier are two alarm circuits which actuate the compass alarm in case of excessive pickoff signal or preamplifier tube failure.

ROLL AND PITCH FOLLOWUP SYSTEM

The roll and pitch followup system (fig. 6-24) detects and eliminates any misalignment between the roll-pitch phantom and the level position maintained by the two gyros. It also positions the roll and pitch synchro data transmitters. The system consists of two E-core pickoffs, two followup amplifiers, and two followup motors, all duplicates of the corresponding components in the azimuth followup system. In addition, the system includes a roll-pitch resolver.

The meridian gyro roll-pitch pickoff is mounted on the meridian gyro cradle and detects any misalignment between the cradle and the meridian gyro's vertical ring. This misalignment is about the meridian gyro's east-west horizontal axis. The roll-pitch phantom, physically linked to the azimuth phantom, will be identically misaligned with the vertical rings of both gyros.

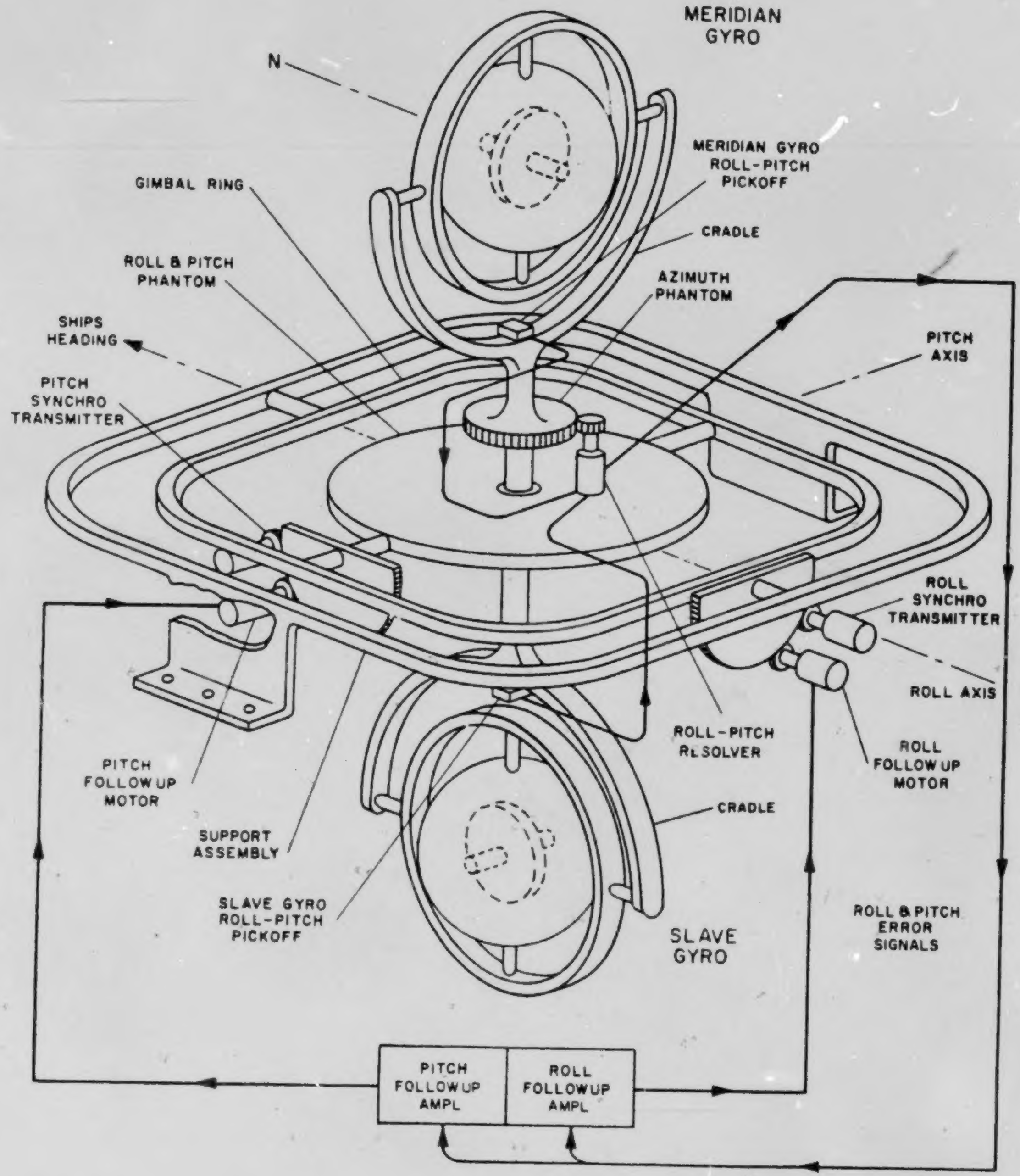
The slave gyro roll-pitch pickoff is mounted on the slave gyro cradle and detects any misalignment between the cradle and the slave gyro's vertical ring. This misalignment is about the slave gyro's north-south horizontal axis. Thus, any misalignment between the roll-pitch phantom and the vertical ring of either gyro produces a roll-pitch pickoff signal.

A pitch followup motor is mounted on the gimbal ring and meshes with the pitch gear on the roll-pitch phantom. It positions the roll-pitch phantom about the pitch axis. A roll followup motor is mounted on the support assembly and meshed with the roll gear on the gimbal ring. It positions the roll-pitch phantom about the roll axis, through the gimbal ring.

On the north-south course, the pickoff signal from the meridian gyro roll-pitch pickoff, if fed through the pitch followup amplifier to the pitch followup motor, will compensate for the effect of pitch. Similarly, if the pickoff signal from the slave gyro roll-pitch pickoff were fed through the roll followup amplifier to the roll followup motor, it will compensate for the effect of roll.

On an east-west course, however, the meridian gyro roll-pitch pickoff would have to be fed to the roll followup amplifier and motor, to compensate for roll, and the slave gyro roll-pitch pickoff would have to be fed to the pitch followup amplifier and motor to compensate for pitch. It follows, therfore, that on any intermediate course, the roll-pitch motions of the ship will have components acting about both north-south and east-west axes, and both roll-pitch pickoffs will react to both roll and pitch. As a result, the two pickoff signals must be divided into proper proportions to each followup amplifier and motor to maintain the horizontal stability of the roll-pitch phantom. The own ship's course determines these proper proportions, and they are obtained from the roll-pitch resolver.

The roll-pitch resolver has its rotor positioned corresponding to own ship's course by the azimuth followup system, as mentioned previously. The meridian gyro roll-pitch pickoff signal is fed to one resolver rotor winding, and the slave gyro roll-pitch pickoff signal is fed to the other rotor winding. The resolver resolves its own ship's course and roll-pitch pickoff input signals into output signals of proper proportions,


MERIDIAN GYRO
N
MERIDIAN GYRO ROLL-PITCH PICKOFF
GIMBAL RING
CRADLE
ROLL & PITCH PHANTOM
AZIMUTH PHANTOM
SHIPS HEADING
PITCH AXIS
PITCH SYNCHRO TRANSMITTER
ROLL SYNCHRO TRANSMITTER
ROLL AXIS
ROLL-PITCH RESOLVER
PITCH FOLLOW UP MOTOR
ROLL FOLLOW UP MOTOR
CRADLE
SUPPORT ASSEMBLY
SLAVE GYRO ROLL-PITCH PICKOFF
SLAVE GYRO
ROLL & PITCH ERROR SIGNALS
PITCH FOLLOWUP AMPL
ROLL FOLLOWUP AMPL

27.181

Figure 6-24.—Simplified diagram of roll and pitch followup system.

to the followup amplifiers. The followup motors position the roll-pitch phantom until the pickoffs are restored to their neutral position and, at the same time, they position 2- and 36-speed roll and pitch synchro data transmitters.

ALARM SYSTEM

An alarm system is incorporated in the Mk 19 gyrocompass system to the extent that each loop in the system will give multiple alarm warnings when a trouble develops in that loop. In addition, as trouble may also develop in the alarm circuits, the circuits are so arranged to give alarm warnings when they themselves become defective. Normal tube current is used in each alarm circuit to energize an alarm relay. Therefore, if trouble develops within a circuit to reduce tube current, the relay will deenergize and actuate the alarm.

STARTING CONTROL SYSTEMS

To aid in starting and operating the master compass, two auxiliary control systems are provided: the starting system and the fast settling system.

During starting, the starting system levels the gyros and brings the meridian gyro to the meridian in as short a time as possible with a minimum number of manual operations required of the compass operator. The system includes a fast erect system, the system control assembly, and part of the control panel.

When the compass is to be started, the roll-pitch phantom will be off its level position. The fast erect system greatly reduces the time required to bring the roll-pitch phantom (and therefore the gyros as they are caged to their vertical rings and the azimuth phantom during starting) to a level position. This system utilizes a small stabilizer, or start gyro, mounted in the gimbal, which when started, comes very quickly to a vertical position, providing a fairly accurate level reference for the roll-pitch phantom.

The fast-settling system reduces the compass period and increases the percent of damping during starting, which reduces the time required for the gyros to assume a true level position and for the meridian gyro to settle on the true meridian.

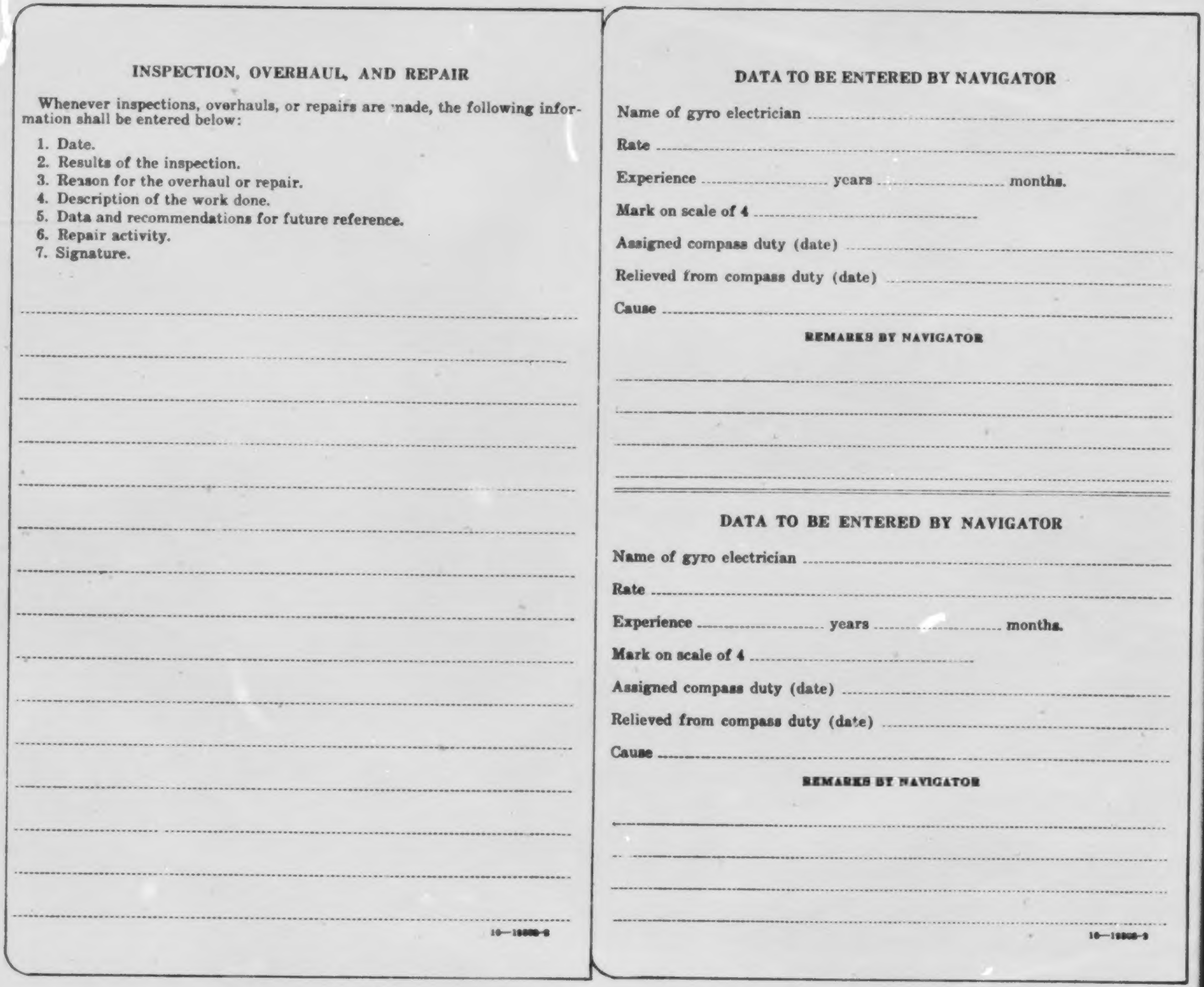
GYROCOMPASS RECORDS AND LOGS

A Gyro Service Record Book is provided with each gyrocompass. The book stays with its gyrocompass and is a record of the compass from its construction through its entire life cycle. The book contains acceptance, test, and installation data, as well as overhaul, repair, and inspections conducted by off-ship activities. In the event a compass is to be removed from a ship, the appropriate entries are made in its Gyro Service Record Book, and the book is transferred with the gyrocompass.

Maintaining the Gyro Service Record Book is required by NAVSEA Systems Command. Instructions, procedures in case of its loss, etc, are found in the front of the Gyro Service Record Book and in Naval Ship's Technical Manual chapter 9240. Two pages are shown in figure 6-25. The page entitled "Inspection, overhaul, and repair" is completed and signed by the gyro electrician who completes the repair. In the event unfavorable conditions are found during an inspection by an off-ship facility, a report must be made to the commanding officer. Planned maintenance completed by ship's force personnel is recorded by normal PMS reporting procedures and is not recorded in this book. However, a fault found during PMS, and then repaired will be entered in the Gyro Service Record Book, as well as reported through MDCS.

U.S. Navy Regulations and OPNAVINST 3120.32 assign responsibility for the care and maintenance of the gyrocompass equipment to The Engineer Officer and Electrical Officer. The Gyrocompass Service Record book has items to be completed by the navigator. However, these are normally completed by either the Engineer Officer or delegated to the Electrical Officer who may also be designated as the gyro officer.

Some ships and type commands require that additional, locally prepared logs, records, etc, be



INSPECTION, OVERHAUL, AND REPAIR

Whenever inspections, overhauls, or repairs are made, the following information shall be entered below:

1. Date.
2. Results of the inspection.
3. Reason for the overhaul or repair.
4. Description of the work done.
5. Data and recommendations for future reference.
6. Repair activity.
7. Signature.

DATA TO BE ENTERED BY NAVIGATOR

Name of gyro electrician ....

Rate ....

Experience .... years .... months.

Mark on scale of 4 ....

Assigned compass duty (date) ....

Relieved from compass duty (date) ....

Cause ....

REMARKS BY NAVIGATOR

DATA TO BE ENTERED BY NAVIGATOR

Name of gyro electrician ....

Rate ....

Experience .... years .... months.

Mark on scale of 4 ....

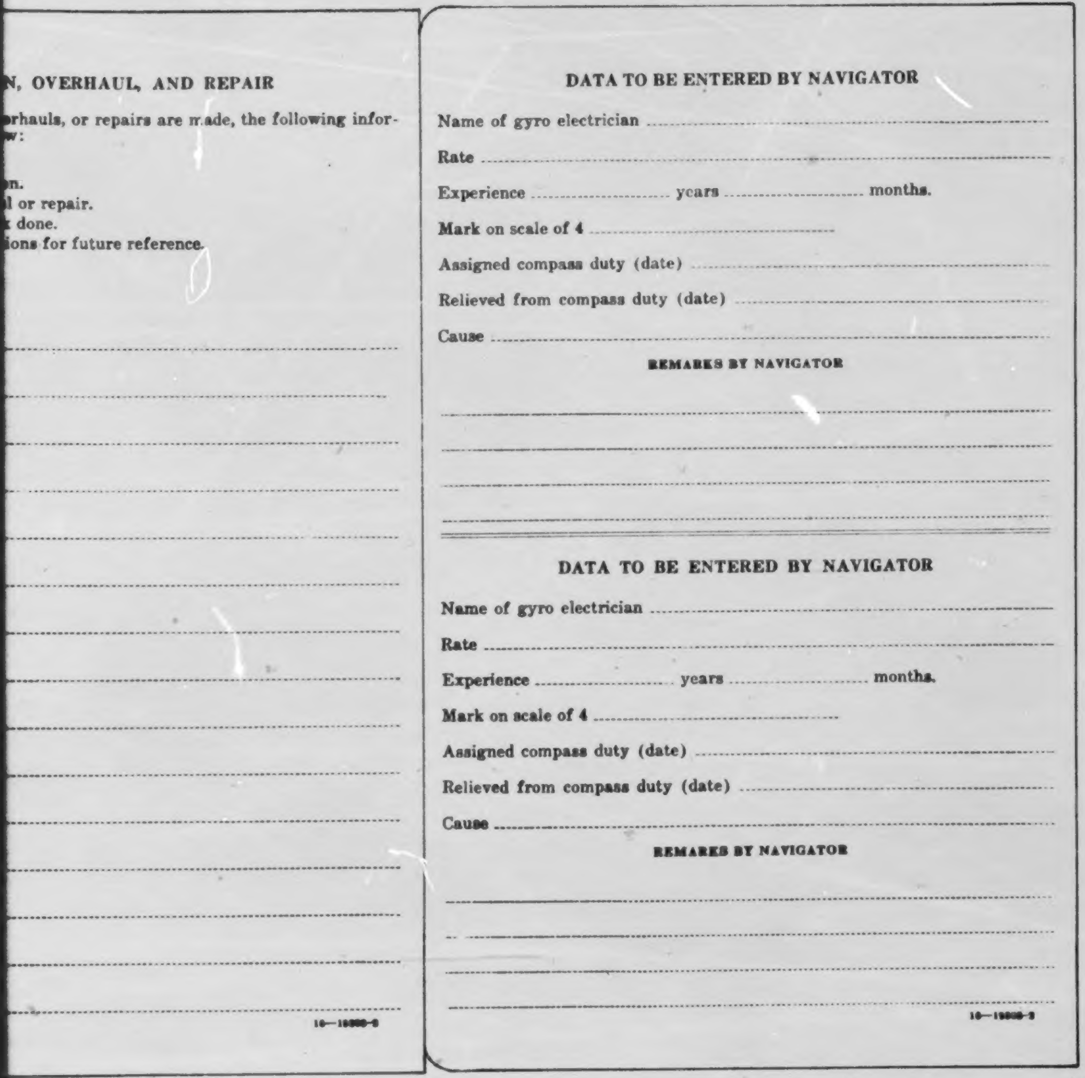
Assigned compass duty (date) ....

Relieved from compass duty (date) ....

Cause ....

REMARKS BY NAVIGATOR

Figure 6-25.—Gyrocompass service record book page.



N, OVERHAUL, AND REPAIR

rhauls, or repairs are made, the following infor-
w:

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l or repair.
k done.
ions for future reference.

10—[illegible]

DATA TO BE ENTERED BY NAVIGATOR

Name of gyro electrician ....
Rate ....
Experience .... years .... months.
Mark on scale of 4 ....
Assigned compass duty (date) ....
Relieved from compass duty (date) ....
Cause ....

REMARKS BY NAVIGATOR

DATA TO BE ENTERED BY NAVIGATOR

Name of gyro electrician ....
Rate ....
Experience .... years .... months.
Mark on scale of 4 ....
Assigned compass duty (date) ....
Relieved from compass duty (date) ....
Cause ....

REMARKS BY NAVIGATOR

10—[illegible]

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Figure 6-25.—Gyrocompass service record book page.

maintained. If required, these records should be maintained completely and accurately and checked routinely by supervisory personnel. A major problem with all records is that, when neglected or when entries are omitted for any reason, they give a false record of reliability. Therefore, all records including MDCS documentation must be checked to ensure that they are dated, complete, and accurate.

Although not maintained by the electrical division personnel, the *Magnetic Compass Record Book* (NAVSHIPS 1101) can be used to get data on the accuracy of the ships gyrocompass system. This is a legal record required by Navy Regulations and OPNAVINST 3120.32 and is maintained by the Quartermasters under the supervision of the Navigator. It contains a record of errors between the forward and after gyrocompasses, steering repeater, and the magnetic compass; entries are made every half hour while the ship is underway.

MAINTENANCE AND REPAIR

The gyrocompasses presently in use will give little trouble if they are properly maintained and if operator/repair personnel are properly trained, motivated, and supervised.

All persons associated with the gyrocompass installation should complete the applicable portions of the Personnel Qualification Standards for that particular type of gyrocompass system. If correctly used, the PQS will ensure that personnel assigned to the operation, maintenance, and watchstanding duties have the knowledge necessary to adequately perform these duties. Supervision will ensure that personnel are carrying out these duties in the prescribed manner.

Corrective maintenance must be performed by knowledgeable personnel who follow the manufacturer's manual. Formal training on a particular gyrocompass system, although desirable, is not a necessity. The gyro electrician must, however, be thoroughly familiar with the manufacturer's manual and the installed system. It should be stressed that the manufacturer's manual is the ultimate aid in all phases of training and repair. It contains sections devoted to the localization and isolation of malfunctions, therefore all work must be conducted by persons familiar with these procedures. The manufacturer's manual not only indicates procedures that should be followed, but also warns of what cannot be done without causing further damage to the system. An improperly trained or careless repairman who is unfamiliar with, or is not following, the manufacturer's manual can easily cause additional problems. For example, the movement of a weight on a mechanical gyro or the turning of the wrong potentiometer in an electronic gyrocompass system can change a period or dampening setting which will require recalibration of the gyrocompass system at a shore based repair facility.

All corrective maintenance and inspections conducted by outside activities must be recorded in the Gyro Service Record Book and through MDCS documentation to provide accurate indications of reliability, cost, and repair man-hours. The PQS, PMS, and MDCS programs standardize training, documentation, and preventive and corrective maintenance. These programs, if properly implemented and supervised, will ensure the most effective and reliable operation of the gyrocompass system. If these programs are administered in a haphazard manner, equipment operation will deteriorate, although ship's record indicate reliable operation with a minimum of corrective maintenance time.

OPERATION

Because of its importance to the ship's safety during underway periods and in the operation and maintenance of weapons systems, set gyrocompass operating procedures should be prescribed for starting, operating, and securing the gyrocompass system. This chapter indicates basic requirements. Type and local commands will have variations of these procedures and they should be followed for your particular ship and conditions.

When the gyrocompass is started for any reason, an entry should be made in the

Engineering Log. When the gyrocompass is started prior to getting underway, the station keeping the Preparation for Getting Underway Check-Off List (usually the Quarterdeck) must also be notified. Prior to getting underway, usually when the Special Sea and Anchor Detail is set, entries should be made in both the Engineering Log and the Quartermasters Notebook, indicating which gyrocompass is the master (on line). While underway, the master will be changed only in the event of a casualty or with prior approval. The OOD must be kept fully informed of all of these changes. In the event of a casualty, the Bridge must be notified immediately, and the engineering officer of the watch should be notified as soon as possible; both will be informed of the nature of the casualty which necessitated the change.

When the ship enters port, the gyrocompass systems should be secured only after permission has been obtained from the Navigator and the Commanding Officer, via the Engineering Officer. Although not required for ship's safety, it may be advantageous to find out what requirements the Weapons Department has for the inport period, as many of their preventive maintenance procedures require gyro inputs. Mutual coordination and cooperation with other divisions which may require gyrocompass inputs while inport, will aid in the most efficient use of the system and also, keep operating hours at a minimum while still providing required services.

CHAPTER 7

NO BREAK POWER SUPPLIES AND STATIC INVERTERS

As the Navy expands into the comparatively new field of solid state technology, so does the work of an Electrician's Mate. This chapter will discuss the operation and maintenance of no break power supplies and static inverters. Personnel lacking a thorough understanding of solid state circuitry, components, or terms should review *Basic Electronics*, NAVEDTRA 10087 (Revised).

A no break power supply is designed to provide uninterrupted electrical power to loads by automatic takeover of the power supply should the normal supply fail or momentarily deteriorate beyond the demands of the system. No break power supplies are provided for communication systems, computers, navigational equipment, and related equipment where even a momentary loss of power would cause a permanent loss of information resulting in the need to recycle or reprogram the equipment. Since equipment requiring no break power normally requires closely regulated power, no break power supplies are designed to provide not only uninterrupted power, but also to provide power that is regulated to meet the needs of the equipment it serves.

COMPONENTS

The no break uninterrupted power supply system consists of two major assemblies plus the storage batteries. The control cabinet and motor-generated set is illustrated in figure 7-1.

The control cabinet contains all the control and monitoring equipment. The motor-generator is a single-shaft unit. Either section of the motor-generator can perform as the motor with the other as the generator. This permits two operational modes; NORMAL and STOP GAP.

NORMAL operation uses the normal supply (ship's generators) with the motor-generator driven by the a.c. motor from the ship's supply while the d.c. generator is charging batteries.

In STOP GAP operation the motor-generator is driven by the d.c. motor with power from the batteries. Under this condition the a.c. generator provides the critical load requirements.

OPERATION

Normal ship's power, as shown in figure 7-2, is applied to the voltage and frequency monitors. If the monitors sense that the normal power is within the frequency and voltage limits required, relay action (relay #1) will allow the normal power to be applied to the load and other circuitry. (It should be noted that the relay numbers in figure 7-2 refer to relay action sequence rather than relay designations.) Power is applied to the relay control power circuit from the battery.

When the system is turned on, the motor-generator will accelerate to approximately synchronous speed as an induction motor before a time delay relay is energized. When the delay energizes (relay #2) it applies normal power to the a.c. field rectifier via the a.c. voltage regulator for application to the a.c. motor as field excitation to allow synchronous motor operation. At the same time the d.c. generator is rerouted to the d.c. supply (relay #3) to prevent starting the motor-generator set on d.c. and to charge the batteries. The system is now operating in NORMAL mode.

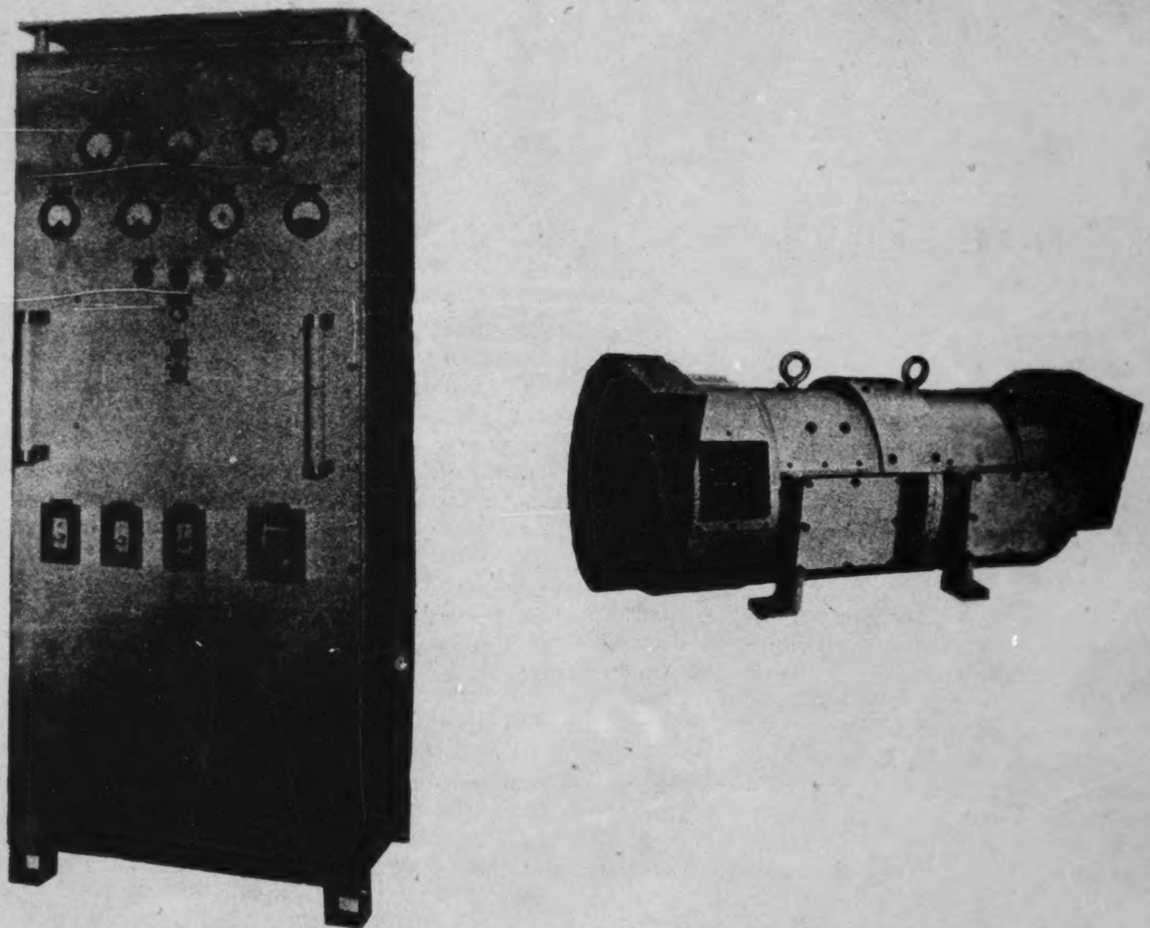

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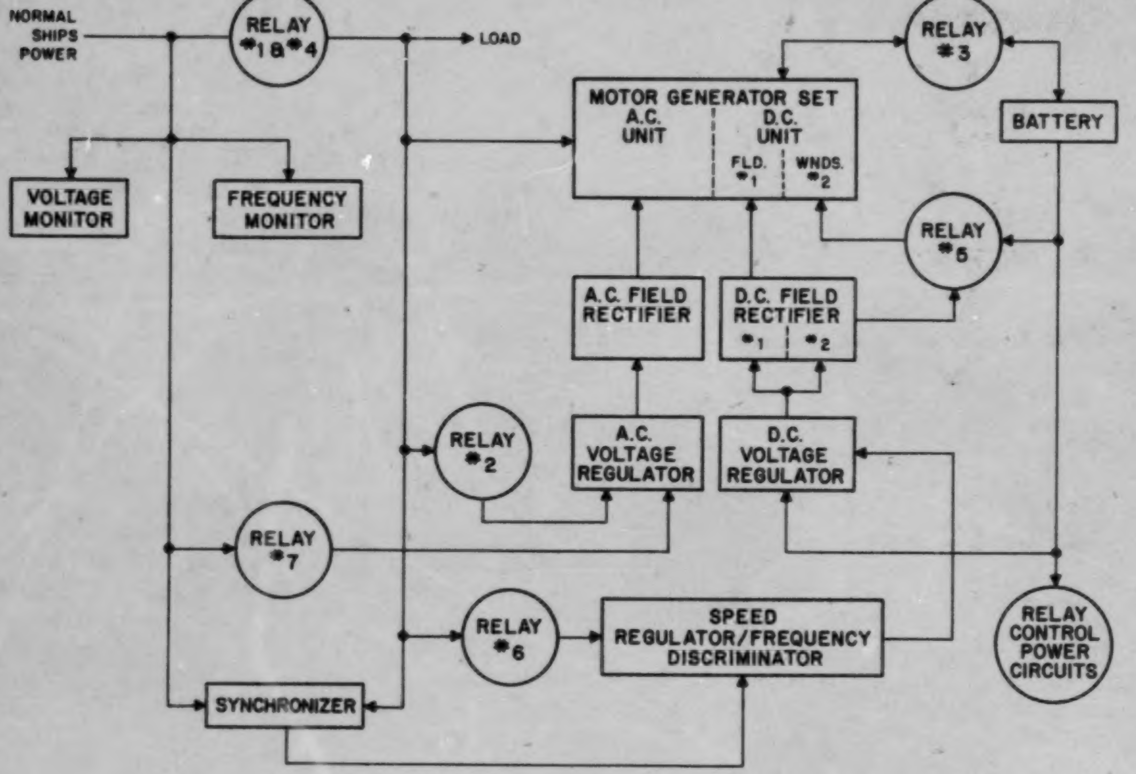
Figure 7-1.—No break uninterrupted power supply system components.

If the normal supply falls out of its limits in either voltage or frequency, the respective monitor will sense it, and relay action (relay #4) will shut down the motor-generator set. At the same time the d.c. generator field is disconnected from the d.c. field rectifier #2 and connected directly to the battery supply (relay #5). The d.c. motor speed regulator and the a.c. generator voltage regulator are energized (relay #6 and #7) to maintain the required motor speed and to control the load voltage. The system is now in the STOP GAP mode.

If the reason for switching modes had been a voltage drop, the voltage would not have dropped below 317 volts and the transition would have been accomplished within one second. In the case of a frequency drop, the change is made within two seconds and the frequency does not drop below 54 Hz.

When the ship's power returns to the specified limits (discussed later), the synchronizer will have the normal power at one side and the a.c. generator power at the other. It will automatically adjust the speed regulator to


NORMAL SHIPS POWER
RELAY *1 & *4
LOAD
RELAY *3
MOTOR GENERATOR SET
A.C. UNIT
D.C. UNIT
FLD. *1
WNDS. *2
BATTERY
VOLTAGE MONITOR
FREQUENCY MONITOR
RELAY *5
A.C. FIELD RECTIFIER
D.C. FIELD RECTIFIER
*1
*2
RELAY *2
A.C. VOLTAGE REGULATOR
D.C. VOLTAGE REGULATOR
RELAY *7
RELAY *6
SPEED REGULATOR/FREQUENCY DISCRIMINATOR
RELAY CONTROL POWER CIRCUITS
SYNCHRONIZER

111.143

Figure 7-2.–No break uninterrupted power supply system block diagram.

match the generator frequency to the normal power. The matching is accomplished in less than one minute and the system is transferred back to a.c. motor drive and battery charge (NORMAL mode).

MONITOR CIRCUITS

The frequency and voltage monitoring circuits are designed to switch the set from NORMAL to STOP GAP when the input frequency drops below 56 Hz or the input voltage falls below an adjustable limit (330 to 380 volts).

The voltage monitor circuitry is basically the same as the voltage sensing and error voltage detector circuit of the voltage regulator and the frequency monitor is basically the same as the frequency discriminator and error voltage detector circuits. These circuits will be discussed later in this chapter. The big difference in the circuits is the output application. The output of the monitors is used for relay switching, whereas the output of the other circuits is for regulation of either voltage or frequency.

VOLTAGE REGULATOR

The function of the voltage regulator is to maintain the output voltage at the preset value (±2%) regardless of temperature or load variations. The basic circuitry for both the a.c. and d.c. regulators is similar except that the d.c. regulator does not use the six-phase rectifiers in the sensing circuit. Constant generator voltage output is obtained by having the regulating circuit change the voltage feed in response to an error signal.

A differential amplifier is used, in the error voltage detector circuit (fig. 7-3), to compare the generator output voltage, from the voltage sensing circuit, with a reference voltage, developed in the error voltage detector circuit, to produce the error signal. The error signal, acting through the modulator, modifies the timing of the pulse repetition frequency of the unijunction trigger circuits. The controlled pulses are fed to the respective field rectifier to control the average power to the generator field. The rate circuit modifies the error signal to stabilize the voltage regulator.

Voltage Sensing Circuit

The voltage sensing circuit (fig. 7-4) steps down the three phase generator 450-v.a.c. output thru voltage sensing transformer T1 to 25 v.a.c. Each phase is rectified by diodes CR1 thru CR6 and filtered by C1 and C2. This d.c. voltage is proportional to the generator output voltage. The d.c. voltage is applied to voltage divider network R1 thru R4 (R3 can be adjusted to develop the amount of voltage desired as the representative generator output) for comparison to the reference voltage in the error voltage detector circuit.

Error Voltage Detector Circuit

Transistors Q1 and Q2 (fig. 7-4) form a differential amplifier to compare the base voltages of the two transistors. The signal from the voltage sensing circuit is applied to the base of Q1, while the reference voltage is applied to the base of Q2. The reference voltage is applied via R8, which is a factory set and locked reference voltage adjustment.

Resistor R9 is the voltage dropping resistor for CR7, and capacitor C3 reduces the ripple and noise voltages across CR7 to provide a clean d.c. reference voltage. Resistors R6 and R7 are load resistors for transistor Q2.

Any difference between the input voltage at the base of Q1 and the reference voltage at the base of Q2 will produce an error signal (a change in collector current). If the input voltage is higher than the reference voltage, Q1 conducts heavier than Q2 and vice versa when the reference voltage is higher than the input. The voltage drop across R6 is the error voltage which is applied to the base of the modulator Q3.

Modulator Circuits

The modulator circuit (fig. 7-4) modifies the time constant of the RC circuit (C4, R10, and the Q3 collector-emitter resistance). (The collector-emitter resistance is controlled by the current through resistor R6.) An increase in the error signal across R6 decreases the collector-emitter resistance of Q3 and thus

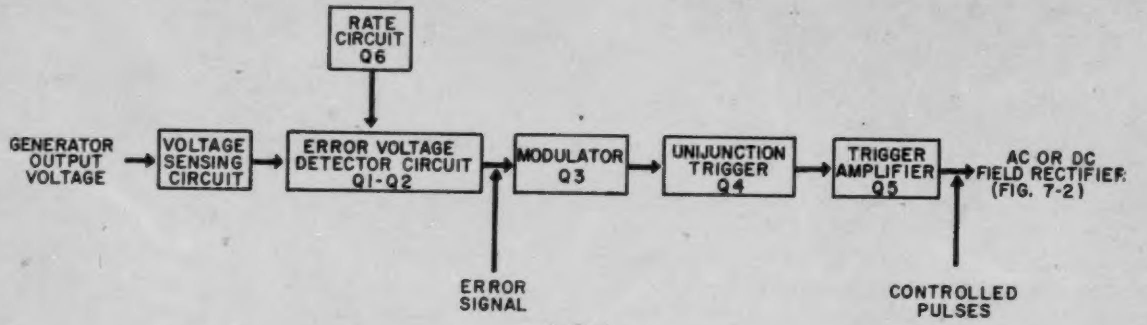


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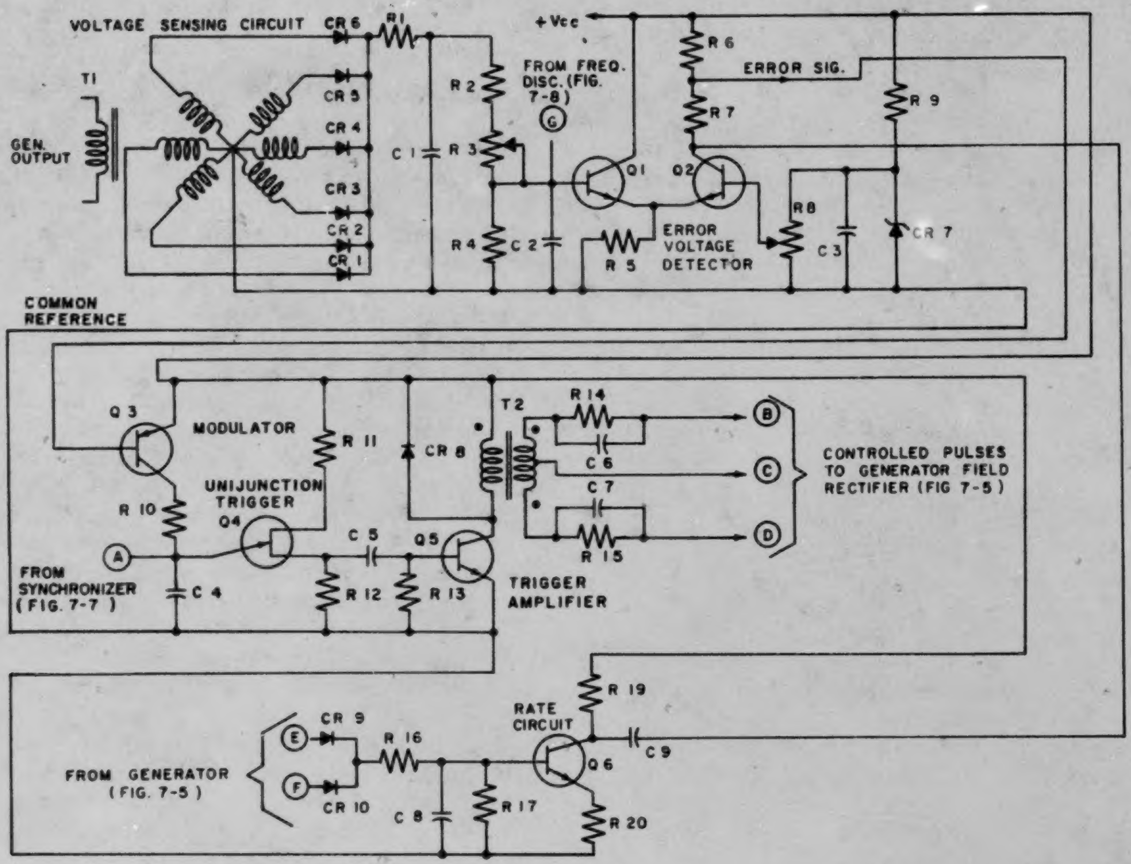
Figure 7-3.—Voltage regulator, block diagram.


VOLTAGE SENSING CIRCUIT
CR 6
R1
+Vcc
T1
GEN. OUTPUT
CR 5
CR 4
CR 3
CR 2
CR 1
R 2
C 1
R 3
R 4
C 2
FROM FREQ. DISC. (FIG. 7-8)
G
Q1
Q2
R 5
ERROR VOLTAGE DETECTOR
R 6
R 7
ERROR SIG.
R 8
C 3
R 9
CR 7
COMMON REFERENCE
Q 3
MODULATOR
R 11
CR 8
T2
R 14
C 6
C 7
R 15
B
C
D
CONTROLLED PULSES TO GENERATOR FIELD RECTIFIER (FIG 7-5)
R 10
UNIJUNCTION TRIGGER
Q4
A
FROM SYNCHRONIZER (FIG. 7-7)
C 4
C 5
Q5
R 12
R 13
TRIGGER AMPLIFIER
R 19
RATE CIRCUIT
C 9
Q 6
CR 9
E
F
R 16
CR 10
FROM GENERATOR (FIG. 7-5)
C 8
R 17
R 20

111.145

Figure 7-4.—Voltage regulator, simplified schematic.

decreases the charge time of C4. If the error signal decreases, the charge time of C4 is increased.

Capacitor C4 discharges when the voltage across it is approximately 9 volts (the peak point voltage of unijunction transistor Q4). A synchronizing circuit (discussed later) clamps C4 to ground, thus delaying the RC time cycle. A rate feedback signal is also applied by the rate circuit to the collector of Q2. This signal modifies the error signal, thus stabilizing the voltage regulator.

Rate Circuit

The function of the rate circuit is to dampen the generator output voltage excursions about a set point. Otherwise the high gain of the voltage regulator would cause the generator output voltage to hunt. The method used for damping the voltage excursion is feeding back an inverted signal (opposite to the error signal) proportional to the rate of voltage change.

The rate circuit (fig. 7-4) consists of a common emitter amplifier (Q6, R19, and R20) and an integrating circuit (R16 and C8). Resistor

R17 is a discharge resistor for C8, and CR9 and CR10 are common rectifiers.

The input is supplied by the generator field rectifier (described later), integrated, and applied as forward base bias to Q6. Any change in the base is amplified and passed by C9 to the collector of the error detector, Q2. As this signal is opposite the error signal, it will decrease conduction and stabilize the circuit.

Unijunction Trigger Circuit

The trigger function is performed by the unijunction trigger circuit (fig. 7-4). Unijunction transistor Q4 is a relaxation oscillator which initiates controlled rate pulses to trigger the field rectifiers. Q4 turns on when the voltage across C4 and the emitter current of Q4 reach preset values. When Q4 conducts, trigger pulses are applied to the trigger amplifier Q5.

Trigger Amplifier Circuit

The trigger amplifier (fig. 7-4) amplifies and shapes the trigger pulses. The circuit is a common emitter amplifier with RC input (R13 and C5) and transformer output (T2).

Transistor Q5 is protected against the inductive kickback voltage of T2 by diode CR8. Resistors R14 and R15 with capacitors C6 and C7 comprise a pulse-shaping network to prolong the life of the SCR's in the field rectifier (fig. 7-5).

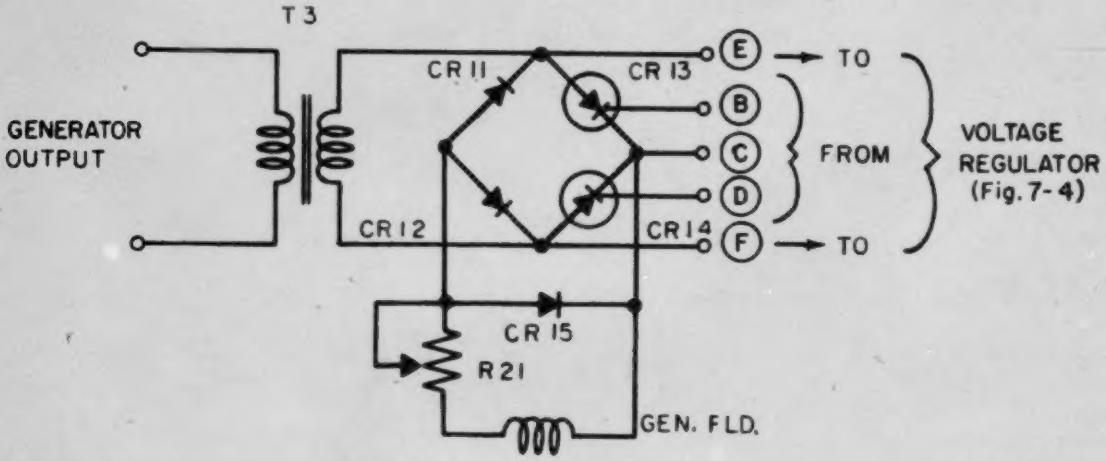
GENERATOR FIELD RECTIFIER

Both the a.c. and d.c. field rectifiers are similar in operation. The function of the generator field rectifier is to provide controlled d.c. power to the generator field in order to regulate the generator output voltage with the field power being proportional to the conduction line of the SCR's.

Transformer T3 (fig. 7-5) transfers voltage from the generator, which is rectified by the bridge rectifier (CR11 thru CR14). The conduction of the bridge is controlled by SCR's CR13 and CR14. One series combination of diode and SCR (CR11, CR13 or CR12, CR14) may conduct for alternate half cycles. The d.c. output is the controlled generator field power.

Diode CR15 is used as an inductive kickback diode to provide a path for the current generated by the collapsing magnetic field of the generator during the idle portion of each cycle. The amount of field power can be adjusted by R21.

The SCR's accomplish power control because they are rectifiers and in an a.c. circuit they conduct during only half of each cycle, and then only after being turned on by a positive gate pulse (from the trigger amplifier). Power



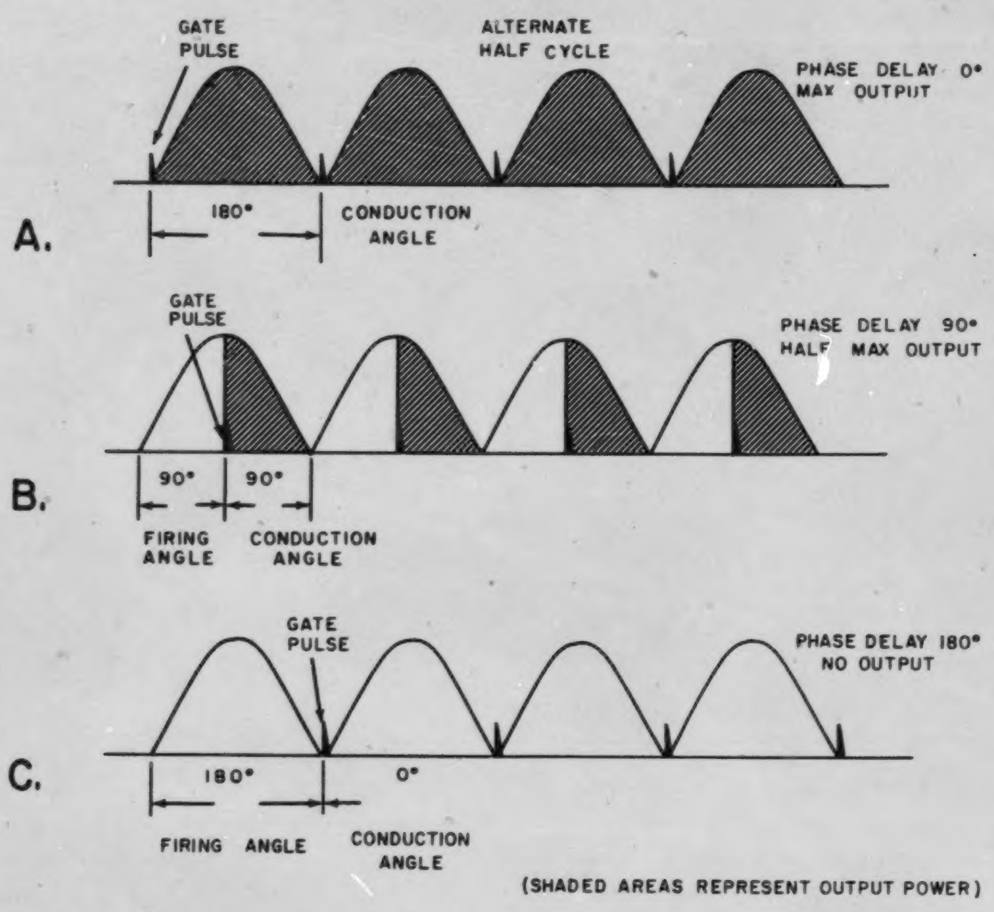
111.146

Figure 7-5.—Generator field rectifier, simplified schematic.

control is accomplished by switching the power on for a greater or smaller portion of the half cycle. Figure 7-6 shows how power can be increased as the firing point is moved along the phase time axis.

The firing point is determined by the position (or timing) of a spiked gate pulse. When applied to the SCR, the pulse turns it on. By controlling the phase of the gate pulse (with respect to the supply voltage) the firing (delay) angle of the SCR gate may be delayed to any point in the cycle up to approximately 180°. Through control of the firing angle, the average power delivered to the load can be adjusted.

Referring to figure 7-6, note that when a gate pulse at zero degrees of the phase time axis (fig. 7-6A) is applied, output power will be applied during the complete half cycle. Figure 7-6B illustrates that power is obtained for one-half of each half cycle when a pulse at 90° of the phase time axis is applied. The other extreme of no output when the phase delay is 180° is represented in figure 7-6C.


GATE PULSE
ALTERNATE HALF CYCLE
PHASE DELAY 0°
MAX OUTPUT
180°
CONDUCTION ANGLE
A.
GATE PULSE
PHASE DELAY 90°
HALF MAX OUTPUT
90°
90°
B.
FIRING ANGLE
CONDUCTION ANGLE
GATE PULSE
PHASE DELAY 180°
NO OUTPUT
C.
180°
0°
FIRING ANGLE
CONDUCTION ANGLE
(SHADED AREAS REPRESENT OUTPUT POWER)

111.147

Figure 7-6.—Phase shift of gate pulse.

SYNCHRONIZER

The function of the synchronizer is to assure that the firing angle is always reckoned from the instant the supply voltage crosses the zero axis at each positive half cycle (fig. 7-6A). As illustrated in figure 7-7, when the SCR's are not conducting, an alternate bridge rectifier circuit is. This alternate bridge consists of diode CR12, resistor R21, the generator field, resistors R23 and R22, diode CR16, and the secondary of T3 (solid arrows). During the alternate half cycle, the path (dashed arrows) is the same except that diodes CR11 and CR17 are used.

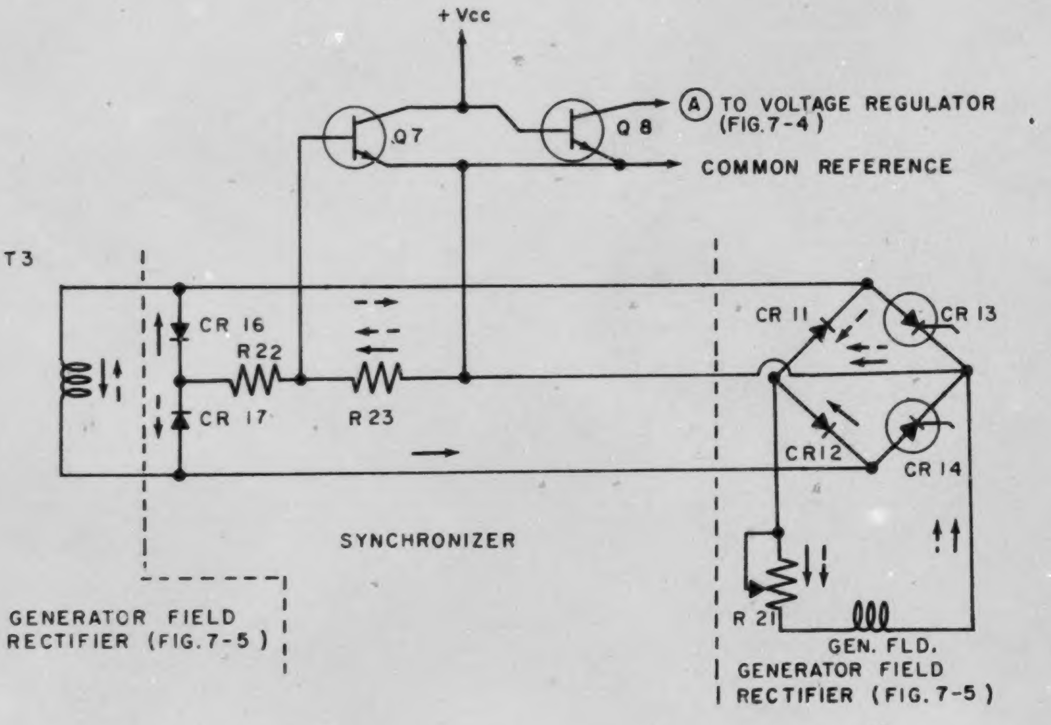
When the alternate bridge rectifier conducts, the voltage across R23 permits C4 (fig. 7-4) to charge, introducing the phase delay of the SCR gate pulse. Firing of SCR's CR13 and CR14 applies equal potential of both ends of voltage divider R22 and R23. This removes the voltage drop across R23 and thus allows Q7 to turn off and Q8 to turn on. Thus the timing capacitor C4 is clamped until the start of the next half cycle.

FREQUENCY DISCRIMINATOR

The speed/frequency regulator automatically maintains the motor speed and the generator frequency at a preset value despite line variations or load changes.

Constant output frequency is obtained by automatically adjusting the power to the motor control field in response to a frequency discriminator. The frequency discriminator converts the generator output frequency to a voltage signal which is in direct proportion to the speed/frequency of the motor generator.

The speed/frequency regulator circuit is the same as the voltage regulator previously discussed. The operational difference is that the


+Vcc
Q7
Q 8
Ⓐ TO VOLTAGE REGULATOR (FIG.7-4)
COMMON REFERENCE
T3
CR 16
R22
CR 17
R 23
CR 11
CR 13
CR12
CR 14
R 21
GEN. FLD.
SYNCHRONIZER
GENERATOR FIELD RECTIFIER (FIG.7-5)
GENERATOR FIELD RECTIFIER (FIG. 7-5)

111.148

Figure 7-7.—Synchronizer, simplified schematic.

voltage regulator requires an increase in generator output voltage to cause a decrease in generator field current, but in the frequency regulator an increase in frequency causes the field current to increase.

The discriminator circuit is shown in figure 7-8. Essentially it consists of a one-shot multivibrator which puts out a constant width pulse whenever a trigger pulse is applied. The trigger circuitry is designed so that a pulse is applied six times each output cycle in order to obtain a high enough sampling rate to decrease the response time of the circuit. The multivibrator output is integrated in order to provide a d.c. voltage that is proportional and linear with frequency.

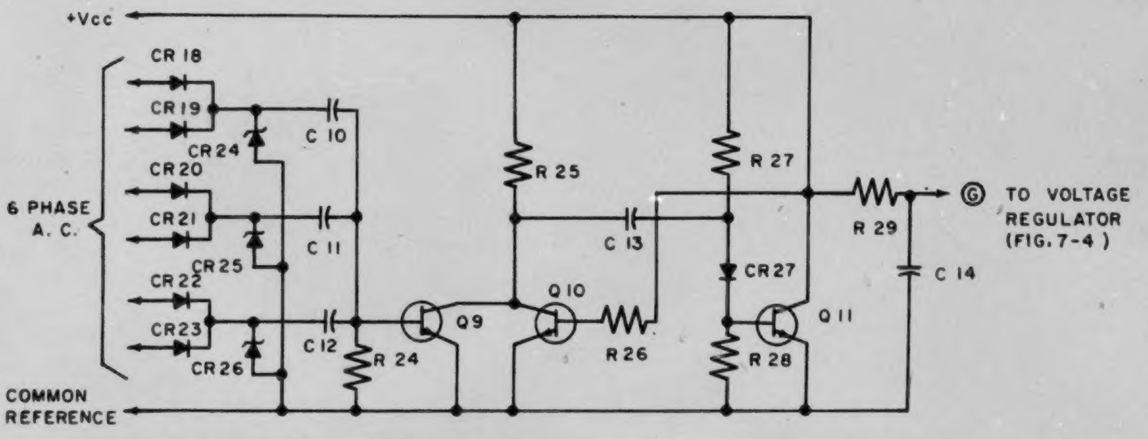
The positive collector voltage input furnishes the circuitry operating biases, and six-phase a.c. is used to obtain the trigger pulses. The trigger circuitry consists of three single-phase full-wave rectifiers (CR18 and CR19, CR20 and CR21, and CR22 and CR23). Each is driven from a winding of the T1 star secondary (fig. 7-4). The rectified voltages are clipped by the zeners (CR24, CR25, and CR26) to obtain a square pulse, which is further shaped by the differentiating circuitry of C10, C11, C12, and R24. The differentiated pulses drive the trigger transistor Q9, which saturates whenever a positive pulse is applied.

Transistors Q10 and Q11 form a one shot multivibrator whose output is a 2-millisecond wide pulse equal in amplitude to the collector voltage. Q11 is normally held on through R27, CR27, and R28. Thus Q10 is held off as its base drive comes from Q11's collector. Since Q9 saturates when a trigger pulse is applied, the collector voltage of Q10 is at ground potential whenever a pulse is applied.

Before the trigger pulse is applied, C13 has been charged to the collector voltage (Vcc) level through resistor R25 with the other end clamped to ground through diode CR27 and the base-emitter junction of Q11. When C13 discharges due to the trigger pulse, it turns off Q11. The collector will rise to the collector voltage level and resistor R26 will apply base current to Q10 to hold it saturated after the trigger pulse ends.

This state (Q10 on, Q11 off) will exist until C13 charges through R27 to a voltage high enough to allow Q11 to become forward biased again. At this time, the output pulse ends since Q11 saturates and the base drive of Q10 is removed. The time duration of the output pulse is controlled by C13 and R27, with CR27 in the circuit to protect the base junction of Q11 from overvoltage.

The output pulse from the collector of Q11 is fed through resistor R29 to integrating



111.149

Figure 7-8.—Frequency discriminator, simplified schematic.

capacitor C14. During the time no output pulse is present, C14 is discharged thru R29 and the collector-emitter junction of Q11. If the frequency of the generator increases, the ratio of charge time to discharge time increases which, in turn increases the discriminator output voltage proportional to the frequency shift. A decrease in frequency does the opposite. The output is applied to the error voltage detector circuit (base of Q1, figure 7-4) or its equivalent in the frequency regulator.

MAINTENANCE

Under normal conditions, the motor generator set and control equipment require inspection and cleaning as designated by the PMS Maintenance Requirement Cards. When the motor generator is inspected, cleanliness, brush operation, condition of brushes and commutator, bearing temperature, and vibration should be observed.

When necessary, remove dust from the wound section with a vacuum cleaner. If a vacuum cleaner is not available, either 30 pounds maximum compressed air or a hand bellows may be used. Be certain that the compressed air does not have any grit, oil, or moisture content. Compressed air should be used with caution, particularly if abrasive particles (carbon, etc.) are present, since these may be driven into the insulation and puncture it or may be forced beneath insulating tapes or other possible trouble spots. If vibration exists, check for loose parts or mounting bolts.

In cleaning the control equipment, a vacuum cleaner or hand bellows should be used. Accumulations of dust or dirt around components can impair the natural air flow and cause overheating.

DAMP WINDINGS

Moisture in windings can soften the insulation and reduce the dielectric strength. However, considerable time is usually required before the moisture will harm the windings. Possible trouble can be spotted and appropriate maintenance action taken if the insulation resistance of the winding is checked.

If the insulation resistance falls below 1 megohm, the windings should be dried out. Three recommended methods of drying are oven drying, forced warm air drying, or low voltage current drying.

The oven drying method requires a maximum temperature of 85° C. The forced warm air method requires a fan to blow warm air across the damp windings. The air must be dry with the temperature below 212° F.

The low voltage current method requires the circulation of a limited direct current through the windings. Care should be taken to ensure that the drying current does not exceed 80 percent of the full load rating. In drying the field winding, the brushes should be removed to prevent marking or pitting the collector rings (which can occur if the brushes carry the drying current).

The insulation resistance should be checked at regular intervals. Remember that when the current method is used, the resistance may drop temporarily as the moisture is forced to the surface of the winding. Drying should continue until the resistance is at least 1 megohm. The drying process can take days in extreme cases. When the windings are dried out, a coating of insulating varnish should be applied.

OIL SOAKED WINDINGS

If oil enters the windings, insulation breakdown may be imminent, and the winding will probably have to be rewound. However, patches of oil should be removed with a clean cloth soaked in an approved solvent. Use the solvent sparingly, being careful not to saturate the insulation as this can cause softening of the insulation. After a solvent has been used for cleaning, one of the drying methods should be applied.

STATIC INVERTER

The need for a highly dependable static (no moving parts) source of 400-hertz power led to the development of the 4345A static inverter. At present the system is employed in SINS (Ships Inertial Navigation System) installations;

however, most of the circuits employed receive wide use throughout IC installations.

The model 4345A Static Inverter delivers a closely regulated source of 400 hertz 3-phase power from a nominal 250 VDC source. Two single-phase static inverters are operated with a controlled 90° phase difference. Pulse width modulation is used for control of the output voltage of each static inverter. The outputs of the two inverters are fed into two scott "T" connected transformers to provide a three-phase output from a 2-phase input.

The components are enclosed in an aluminum cabinet (fig. 7-9). The Meter Panel Assembly contains the instruments and controls necessary for the operation of the equipment. The inverter Module contains a control circuit +30 VDC power supply, a drive circuit +30 VDC power supply, an input sensing and step change adjustment circuit, a synchronizing subassembly, three variable pulse width generators, a frequency standard oscillator, two driver subassemblies, and two silicon control rectifier power stages. The Power stage contains the capacitors, transformers, and filters associated with the power stages of the inverter.

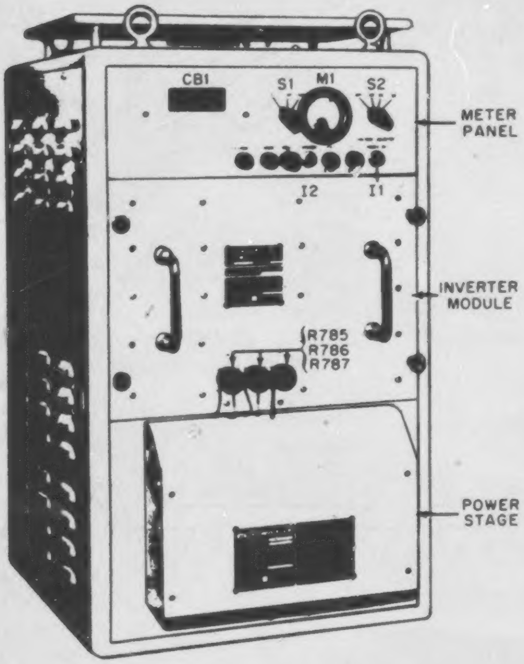


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Figure 7-9.—Static inverter.

FUNCTIONAL DESCRIPTION

A simplified functional block diagram of the model 4345A static inverter is shown in figure 7-10. A brief discussion of the various components and circuits contained in the unit follows.

Oscillator Assembly

The oscillator (fig. 7-10) consists of a 1600-Hz tuning fork controlled oscillator and a binary frequency divider (countdown) circuit. The countdown circuit reduces the 1600-Hz oscillator frequency to an 800-Hz reference frequency required by the inverter control circuits.

Variable Pulse Width Generators

The inverter module contains one variable pulse width generator (VPWG) for each inverter (main and secondary VPWG, fig. 7-10), and one VPWG for controlling the phase angle between the inverters. Each VPWG contains a monostable (one-shot-multivibrator, a modulator circuit, and an inverter output voltage error sensing circuit).

The modulator circuit consists of a transistor and resistors connected in the discharge path of a capacitor. Varying the level of conduction of the transistor varies the discharge time of the capacitor which varies the time the monostable multivibrator remains in the unstable state. The time the monostable multivibrator remains in the unstable state determines the width of the output pulse.

The monostable multivibrator used in the VPWG can be triggered only on positive pulses.

The output voltage error-sensing circuit for each VPWG receives an AC signal (via the feedback loop), proportional to the output voltage of the inverter. The AC signal is converted into a corresponding DC signal,

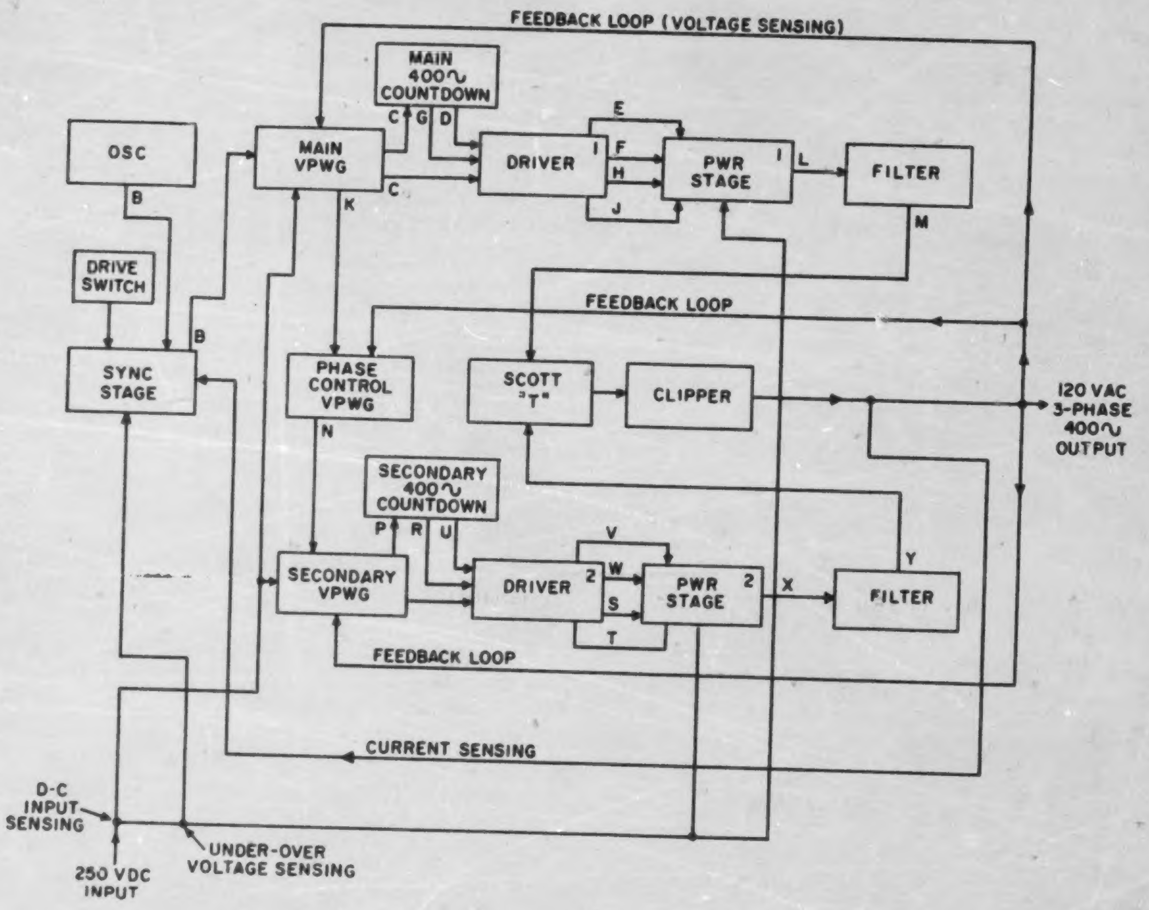
FEEDBACK LOOP (VOLTAGE SENSING)
MAIN 400∿ COUNTDOWN
C
G
D
E
OSC
B
MAIN VPWG
C
DRIVER 1
F
H
J
PWR STAGE 1
L
FILTER
M
K
DRIVE SWITCH
FEEDBACK LOOP
B
SYNC STAGE
PHASE CONTROL VPWG
SCOTT "T"
CLIPPER
120 VAC 3-PHASE 400∿ OUTPUT
N
SECONDARY 400∿ COUNTDOWN
P
R
U
V
Y
SECONDARY VPWG
DRIVER 2
W
S
T
PWR STAGE 2
X
FILTER
FEEDBACK LOOP
CURRENT SENSING
D-C INPUT SENSING
250 VDC INPUT
UNDER-OVER VOLTAGE SENSING

Figure 7-10.—Simplified block diagram of static inverter.

40.80

compared with a reference signal, and the error (difference) signal is used to control the level of conduction of the transistor in the modulating circuit.

The secondary VPWG regulates the output voltage of phase AB, and the phase control and main VPWG regulate the voltages of phases BC and CA respectively. The phase control VPWG also provides a delay in time between triggering of the main and secondary VPWG to control the phase angle between power stages (1 and 2) of the inverters.

The main and secondary VPWG'S deliver one 800 Hz input to each of the driver stages (1 and 2), and another 800-Hz input to a binary countdown circuit which, in turn, delivers two 400-Hz inputs 180° apart to each of the driver stages.

Drivers

Each driver contains four drive pulse generators. Two of the drive pulse generators generate the triggers for the power SCR's ("turn on" SCR's), and the other two generate the triggers for the commutating SCR's ("turn off" SCR's), in the power stages.

A unijunction transistor is utilized to generate the drive pulse trigger.

Power Stages

Each power stage contains three power and three commutating SCRs for each side of the power stage, and a transformer. The SCR's switch the DC source across the primary of the transformer at a 400-Hz rate to produce a 400-Hz square wave output. The square wave output is filtered to produce a sine wave.

The SCR is the semiconductor equivalent of the gas thyratron tube. Once it is made to conduct, it will continue to conduct for the remaining positive half cycle (anode positive with respect to cathode). Neither the removal of the gate voltage nor the reversal of the gate voltage will stop the SCR from conducting. Conduction may be stopped only by completely removing the positive anode to negative cathode voltage or by applying a slightly greater reverse negative anode to positive cathode voltage.

The principle of operation of the power stages can be described by the simplified schematic diagram (fig. 7-11). When power SCR (Q1) is triggered on by an output pulse from the driver, a rising current will flow through primary winding 3-4 of output transformer T1 (through *Q1*, *L1*, and the battery), inducing a voltage in the secondary 6-7 in one direction. By autotransformer action, a voltage is also induced in winding 4-5. This voltage charges capacitor C1 through Q1, CR1, and R1. When commutating SCR (Q3) is triggered on by the driver, the positive voltage from the right plate of C1 is applied through Q3 (Q3 conducting) to the Q3-CR3 junction. This applies a reverse negative anode to positive cathode voltage to Q1 causing Q1 to stop conducting. Capacitor C1 discharges through L1, CR3, and Q3. With Q1 off, the current in winding 3-4 of T1 gradually drops to zero and, slightly later when the 3-4 current ceases, the voltage between secondary terminals 6-7 drops to zero. The voltage between terminals 4-5 also drops to zero. When C1 discharges to zero, Q3 stops conducting. Because of the gradual drop of current in the 3-4 winding, the voltage induced in the 6-7 winding is of reversed polarity and low amplitude.

On the other side of the power stage, power SCR (Q2) is then triggered on by the driver output, and capacitor C2 charges in the same manner as C1 charged. The operation of this side of the power stage is the same as for the side just discussed. The polarity of the output is reversed,

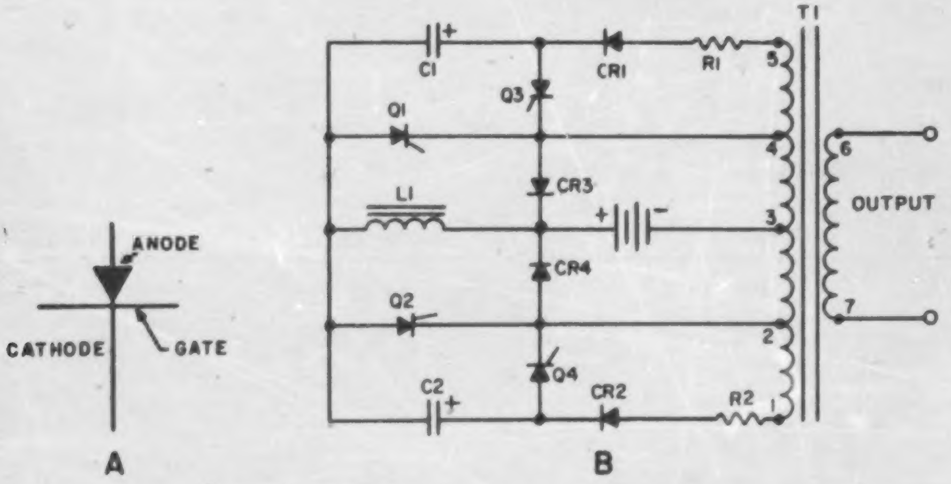

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Figure 7-11.—Power stage, simplified schematic diagram.

however, which completes the square wave output on the secondary of T1.

Filters

The filters (fig. 7-10) convert the square wave outputs of power stages 1 and 2 to sine waves. Each filter consists of one series and four shunt LC filters. The series filter provides a low impedance path for the 400-Hz fundamental frequency and a high impedance path for the odd harmonics in the output. The predominate odd harmonics are filtered out by individual shunt filters. A shunt filter is provided for the third, fifth, seventh, and ninth harmonic. Even harmonics are negligible due to the balanced design of the push-pull power stage.

Scott "T" Transformer

The Scott "T" transformer is a center-tapped autotransformer. The output voltages from the main and secondary inverter filters combine in the Scott "T" transformer to produce a 120 volt, 3-phase output.

Clipper

The 3-phase clipper network consisting of capacitors, resistors, and diodes is connected across the 3-phase output of the Scott "T" transformer. The clipper network functions to reduce voltage transients in the inverter 3-phase output.

Synchronizing Stage

The SYNC stage (fig. 7-10) contains an emitter-coupled binary circuit and a bistable multivibrator. This stage ensures that drive pulses are initiated properly when the unit is turned on. If the drive switch is turned on at the wrong time with respect to the reference signal from the oscillator, operation is delayed until the beginning of a cycle in the reference signal.

The binary circuit in the SYNC stage has three interlock circuits which control the switching of the bistable multivibrator (the "turn on" and "turn off" condition of the inverter). The three interlock signals are provided by the drive switch, the under-over voltage sensing circuit, and the overload-sensing circuit. A positive signal of 20 VDC or greater from either of these three sources will cause the binary circuit to switch, which in turn will cause the bistable multivibrator to switch to the "turn off" condition on the inverter.

The SYNC stage also contains a delayed B-voltage interlock to ensure that the oscillator, VPWG, and synchronizing circuits have sufficient time to stabilize before the inverter is turned on. A unijunction circuit provides a time delay of approximately two seconds after the inverter main power circuit breaker is turned on, before the control circuit +30 VDC is applied to the inverter circuits.

Drive Switch

The drive switch (S1, fig. 7-9) has three positions: OFF, START, and RUN. In the OFF position (with the main power circuit breaker ON), power is supplied to the standby indicator light to indicate that the inverter is in the standby mode, and a +30 VDC signal is supplied to the synchronizing stage. The drive switch also functions in the OFF position to connect the input DC voltage as a source of power for the control circuit +30 VDC power supply.

In the START position power is removed from the indicator light, and the +30 VDC signal to the synchronizing stage is removed allowing signals to pass to properly start the inverter.

When the drive switch is switched to the RUN position, the input DC voltage for the control circuit +30 VDC power supply is disconnected, and a bridge rectified output from phase CA of the inverter is used.

Power Supplies

The power supplies in the inverter are the control circuit +30 VDC power supply and the drive circuit +30 VDC power supply. The control circuit +30 VDC power supply provides power for all control circuits except the drivers and under-over voltage circuits. This power is obtained from the input DC source during the START mode and from phase CA of the inverter output during the RUN mode as mentioned previously.

The drive circuit +30 VDC power supply provides power for the drivers and the under-over voltage circuits. This power is obtained from the inverter input DC voltage.

Overload Circuit

The overload circuit functions to turn the inverter off in case of overload. An overload current from the current sensing circuit produces a DC signal of sufficient amplitude to trigger a unijunction circuit which in turn triggers a bistable multivibrator. The bistable multivibrator output is fed to the binary circuit in the SYNC stage which switches the bistable multivibrator in this stage putting the inverter in the "turn off" condition.

Under-Over Voltage-Sensing Circuit

The under-over voltage-sensing circuit functions to turn the inverter off when the input DC source voltage is out of the operating range (210-355 VDC) of the inverter.

A modified Schmitt trigger circuit is used to supply the interlock signal to the binary circuit in the SYNC stage. The Schmitt trigger is a form of bistable multivibrator. It differs from the conventional bistable multivibrator, however, in that it is at all times sensitive to the amplitude of the input signal. If the amplitude of the input signal is above a specified level, the Schmitt trigger bistable multivibrator will be in one state (one transistor conducting while the other is off): if the amplitude is below a specified level, it will be in the other state.

DC Input Sensing

The DC input sensing circuit functions to compensate for changes (step changes) in the input DC voltage source. A voltage-sensing network composed of resistors and capacitors is connected to the bus that supplies the DC input to the inverter. Positive and negative step changes in the DC supply voltage produces positive and negative pulse outputs from the voltage-sensing network. The output pulses are fed to the pulse width modulator circuit in the main and secondary VPWG's to compensate for the voltage change.

OPERATION CYCLE

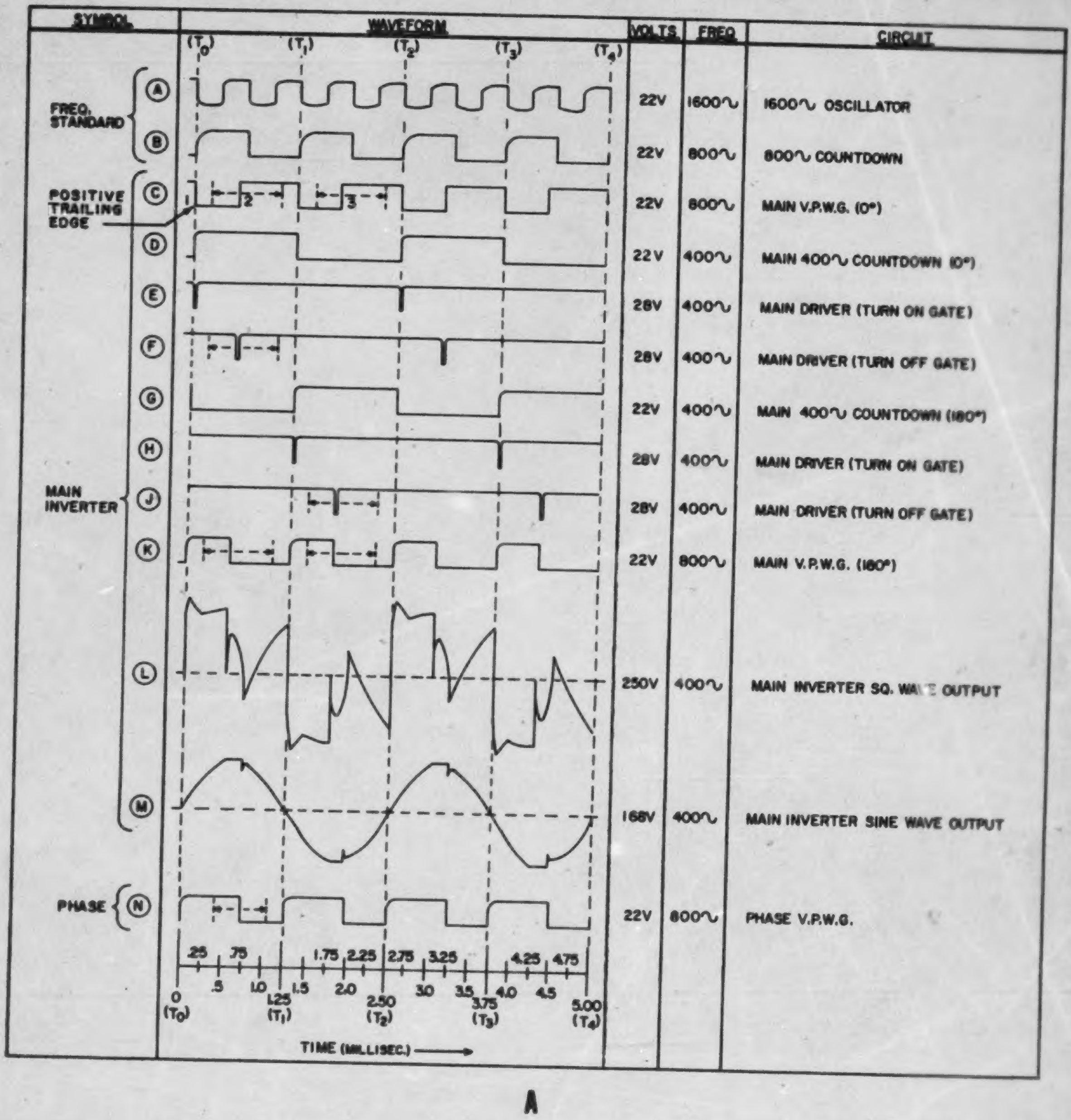
When the main power circuit breaker is on and the drive switch is in the OFF position, the inverter is in the standby mode of operation. The standby mode is composed of a transient and a steady state condition. The transient condition lasts for approximately 2 seconds. This 2-second time delay is provided by the delayed B+ voltage interlock to allow the inverter circuits to reach a steady state, as mentioned previously.

During the standby mode the 800-hertz countdown circuit of the oscillator supplies an 800-Hz square wave voltage to the SYNC stage and the main VPWG (waveform B fig. 7-12A and fig. 7-10). A +30 VDC signal is applied to the binary circuit in the SYNC stage via the drive switch (S1 fig. 7-9) which keeps the bistable multivibrator in the SYNC stage in the "turn off" state.

Turning the drive switch to the START position removes the 300 VDC signal from the binary circuit and allows the first negative-going edge of the 800 Hz square wave (waveform B) to reverse the bistable multivibrator in the SYNC stage. This allows the positive-going edge of waveform B (at time 0 fig. 7-12A) to trigger the monostable multivibrator in the main VPWG (fig. 7-10).

The trailing edge of the first positive half of waveform C (edge No. 1, fig. 7-12A) from the main VPWG triggers the main 40-hertz countdown circuit. The main 400-hertz countdown output (D) triggers the pulse generator in the drive which generates the pulse (E) to trigger the power SCR's for one side of the power stage. The main 400-hertz countdown (D) and the leading edge of the second positive half of waveform C (2, fig. 7-12A) provide coincident gating for the pulse generator in the driver that generates the pulse (F) to trigger the commutating SCR's in this side of the power stage.

The main 400-hertz countdown output (G) triggers the pulse generator in the driver which generates the pulse (H) to trigger the power SCR's in the other half of the power stage. Waveform G and the leading edge of the next positive half of waveform C (3, fig. 7-12A) gate the pulse generator in the drive that generates


SYMBOL
WAVEFORM
VOLTS
FREQ.
CIRCUIT
(T0) (T1) (T2) (T3) (T4)
FREQ. STANDARD
Ⓐ 22V 1600∿ 1600∿ OSCILLATOR
Ⓑ 22V 800∿ 800∿ COUNTDOWN
POSITIVE TRAILING EDGE
Ⓒ 22V 800∿ MAIN V.P.W.G. (0°)
1 2 3
Ⓓ 22V 400∿ MAIN 400∿ COUNTDOWN (0°)
Ⓔ 28V 400∿ MAIN DRIVER (TURN ON GATE)
Ⓕ 28V 400∿ MAIN DRIVER (TURN OFF GATE)
Ⓖ 22V 400∿ MAIN 400∿ COUNTDOWN (180°)
Ⓗ 28V 400∿ MAIN DRIVER (TURN ON GATE)
MAIN INVERTER
Ⓙ 28V 400∿ MAIN DRIVER (TURN OFF GATE)
Ⓚ 22V 800∿ MAIN V.P.W.G. (180°)
Ⓛ 250V 400∿ MAIN INVERTER SQ. WAVE OUTPUT
Ⓜ 168V 400∿ MAIN INVERTER SINE WAVE OUTPUT
PHASE
Ⓝ 22V 800∿ PHASE V.P.W.G.
.25 .75 1.75 2.25 2.75 3.25 4.25 4.75
0 (T0) .5 1.0 1.25 (T1) 1.5 2.0 2.50 (T2) 3.0 3.5 3.75 (T3) 4.0 4.5 5.00 (T4)
TIME (MILLISEC.) ⟶
A

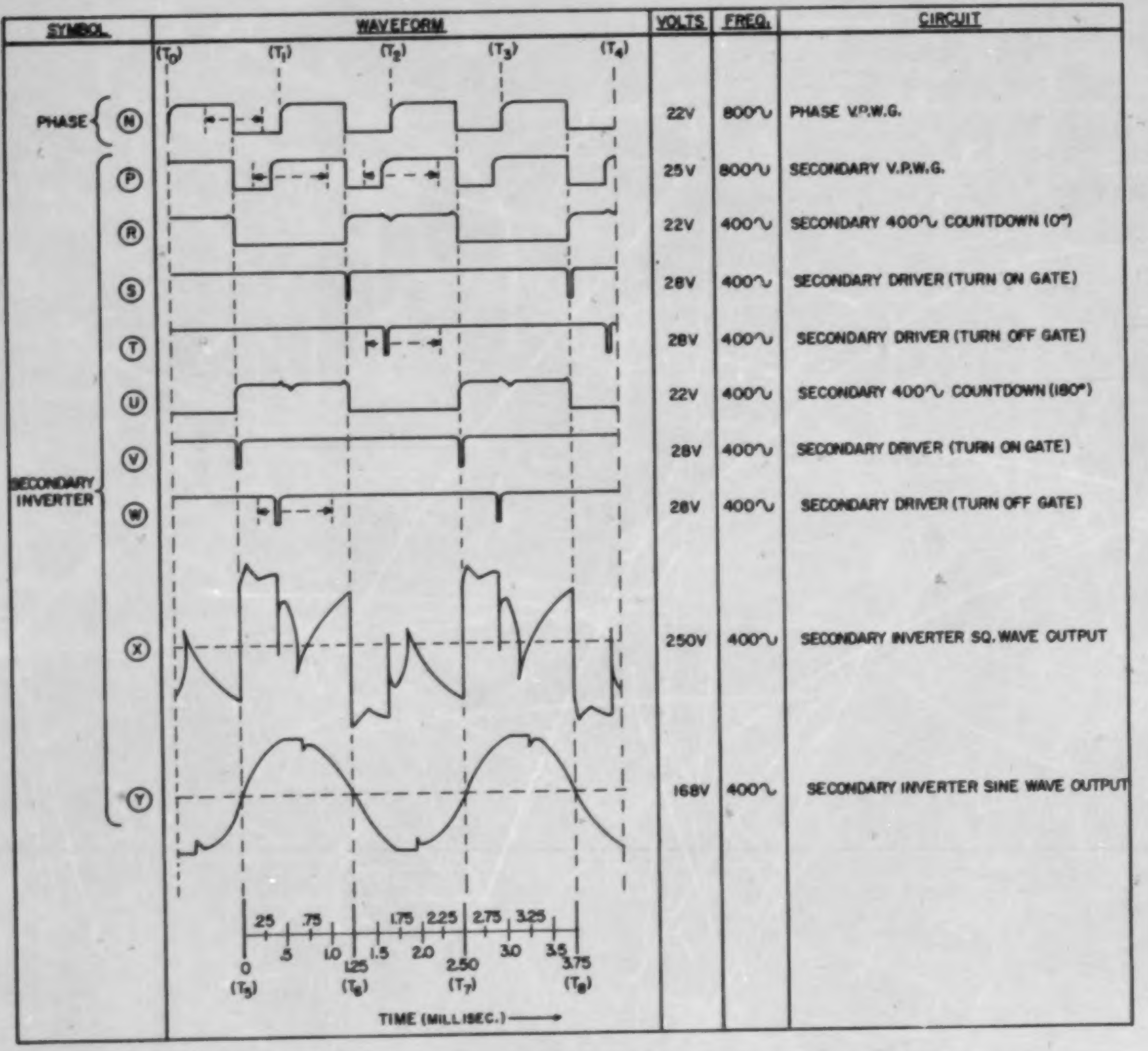
40.82.1

Figure 7-12.—Waveforms.

the pulse (J) to trigger the commutating SCR's in this half of the power stage. The leading edge of waveform C controls the duration of the ON time of the power stage.

The leading edge of the 180° signal (K) from the main VPWG triggers the phase control VPWG. The phase control VPWG provides a delay in time (N) between the main and secondary VPWG's to control the phase angle between the two power stages.

The secondary VPWG is triggered by the trailing edge of the phase control VPWG signal (waveform N fig. 7-12B). The trailing edge of wave P from the secondary VPWG triggers the


SYMBOL
WAVEFORM
VOLTS
FREQ.
CIRCUIT
(T_0)
(T_1)
(T_2)
(T_3)
(T_4)
PHASE
Ⓝ
22V
800∿
PHASE V.P.W.G.
Ⓟ
25V
800∿
SECONDARY V.P.W.G.
Ⓡ
22V
400∿
SECONDARY 400∿ COUNTDOWN (0°)
Ⓢ
28V
400∿
SECONDARY DRIVER (TURN ON GATE)
Ⓣ
28V
400∿
SECONDARY DRIVER (TURN OFF GATE)
Ⓤ
22V
400∿
SECONDARY 400∿ COUNTDOWN (180°)
Ⓥ
28V
400∿
SECONDARY DRIVER (TURN ON GATE)
SECONDARY INVERTER
Ⓦ
28V
400∿
SECONDARY DRIVER (TURN OFF GATE)
Ⓧ
250V
400∿
SECONDARY INVERTER SQ. WAVE OUTPUT
Ⓨ
168V
400∿
SECONDARY INVERTER SINE WAVE OUTPUT
.25
.75
1.75
2.25
2.75
3.25
0
.5
1.0
1.25
1.5
2.0
2.50
3.0
3.5
3.75
(T_5)
(T_6)
(T_7)
(T_8)
TIME (MILLISEC.) ⟶

B

40.82.2

Figure 7-12.—Waveforms—Continued.

secondary 400-hertz countdown. The outputs from the secondary 400-hertz countdown (U and R) and the leading edge of the secondary VPWG output (P) trigger the pulse generators in the secondary driver in the same manner as just described for the main driver. The sequence of operation for the secondary power stage is the same as for the main power stage.

OPERATING PROCEDURE

To operate the static inverter, turn the main power circuit breaker CB1 (fig. 7-9) to ON. Turn the drive switch, S1, to the OFF position. The standby light I2 should light. Turn the drive switch, S1, to the START position. The power on light, I1, should light, and the standby light, I2, should go out. After the output of the inverter has reached a steady state (approximately 2 seconds), turn the drive switch, S1, to the RUN position. Adjust the voltage adjust potentiometers, R785, R786, and R787, (fig. 7-9) to the required output for each phase. Use the voltage selector switch, S2, and meter M1, to reach the voltage of each phase. The output voltages must be adjusted in the following sequence: phase CA, phase AB, then phase BC.

To secure the inverter turn the drive switch, S1, to the OFF position, then turn the power circuit breaker CB1 to OFF.

MAINTENANCE

Maintenance of the static inverter should normally be limited to simple replacement with a new or serviceable module. This will ensure rapid restoration of the inverter into service without risking dangers of handling high test voltages.

Complete familiarization with the theory of operation must be obtained before troubleshooting is attempted. Then follow the step-by-step procedures outlined in the manufacturer's technical manual while using the specified test equipments.

CHAPTER 8

ELECTROHYDRAULIC LOAD-SENSING SPEED GOVERNORS

This chapter will discuss the operation and maintenance of electrohydraulic load-sensing speed governors. If you do not have a thorough understanding of solid state circuitry, components, or terms review *Basic Electronics,* NAVEDTRA 10087 (Revised) and *EIMB Handbook: Electronic Circuits,* NSN 0967-LP-000-0120.

Electrohydraulic load-sensing speed governors have been developed for ship's service generators in electrical systems which require closer frequency regulation than that provided by mechanical type governors. Electrohydraulic governors have been used successfully on both steam-turbine and diesel-driven generators.

An electrohydraulic governor may be operated as an isochronous governor (constant speed at all loads) or with speed droop which permits paralleling with other generators that have conventional fly-weight governors.

The operation of a typical electrohydraulic load-sensing governing system may be generally described as follows. The steam valve or throttle that controls the prime mover fuel supply is operated by an electrohydraulic actuator which responds to the output of a magnetic amplifier. Generator speed and load signals are fed into the transistor amplifier to produce a power output sufficient to operate the electrohydraulic actuator which correctly positions the steam valve or throttle.

The speed signal is usually provided by a small permanent magnet generator driven from the shaft of the prime mover or ship's service generator. The speed signal is sometimes obtained by sensing the output frequency of the ship's service generator, but the loss of signal in case of short circuit on the generator is a disadvantage of this method. The speed signal is applied to a frequency sensitive and reference circuit in the governor control unit. The output of this circuit is an error signal if there is any deviation from rated speed. This error signal is applied to the transistor amplifier and acts to restore rated speed. Stability is obtained by the use of electrical feedback circuits.

Load-measuring circuits are used in the electrohydraulic governor to obtain proper load ratio on each paralleled generator. Most governing systems are so designed that any change in load produces a signal which is fed into the transistor amplifier and acts to offset any anticipated speed change due to load change. The load-measuring circuits on governors of all generators that operate in parallel are connected by a tie cable. The governor may be designed or preset so that each paralleled generator will equally share the total load or a load ratio adjustment may be provided. Any deviation in proper load ratio produces a circulating current in the tie cable. This circulating current acts in the transistor amplifier circuit to increase or decrease fuel supplied to the generator prime movers until proper load ratio is achieved.

The steady state and transient frequency requirements for Type II power can be met with electrohydraulic governors of the type just described. However, a motor generator or static converter will still be required for Type III voltage control.

The electrohydraulic load-sensing governor used in this discussion is made up of four major units (fig. 8-1)—the EG-M control box, the load signal box, the EG-R hydraulic actuator, and the valve operator.

OPERATION

Look at the block diagram in figure 8-2. The input signal (voltage) is proportional to the speed of the permanent magnet generator (PMG) and is applied to the EG-M control box. The control box compares this voltage with a reference voltage and, if there is a difference, supplies an output voltage to energize the EG-R hydraulic actuator. A pilot valve plunger in the

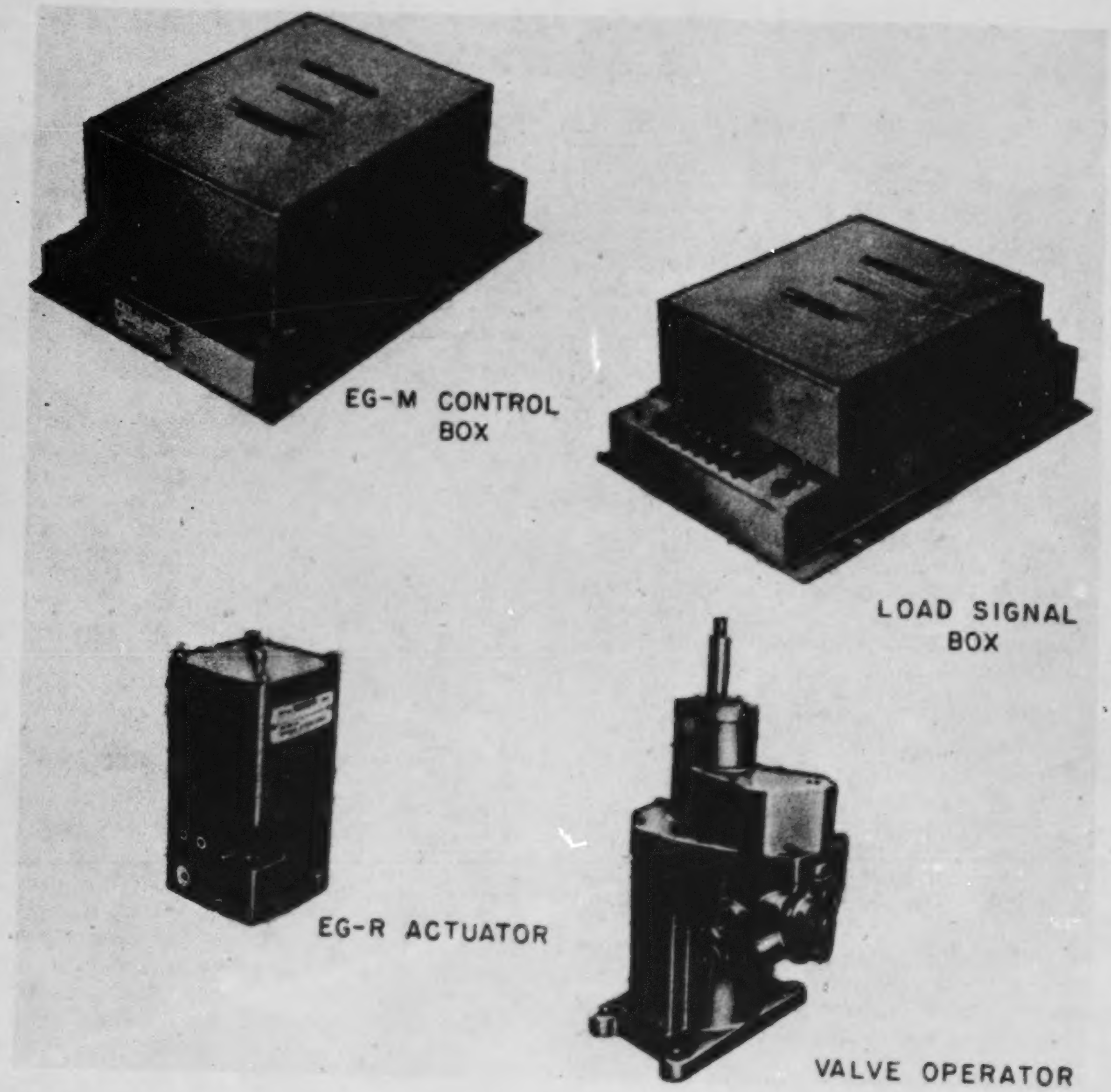

EG-M CONTROL BOX
LOAD SIGNAL BOX
EG-R ACTUATOR
VALVE OPERATOR

Figure 8-1.—Electrohydraulic load-sensing governor system components.

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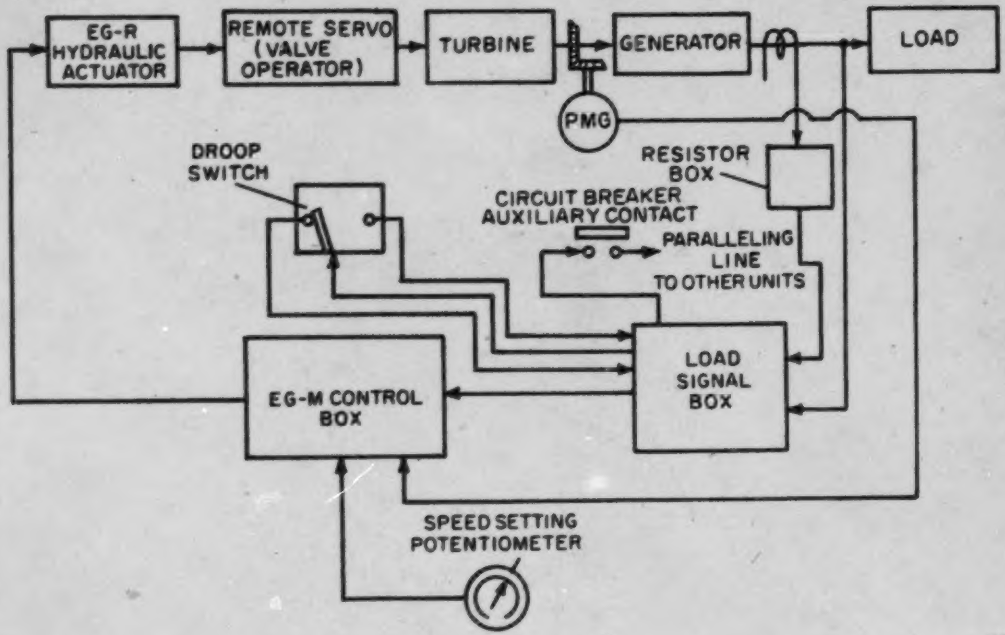

EG-R
HYDRAULIC
ACTUATOR
REMOTE SERVO
(VALVE
OPERATOR)
TURBINE
GENERATOR
LOAD
PMG
DROOP
SWITCH
RESISTOR
BOX
CIRCUIT BREAKER
AUXILIARY CONTACT
PARALLELING
LINE
TO OTHER UNITS
LOAD
SIGNAL
BOX
EG-M CONTROL
BOX
SPEED SETTING
POTENTIOMETER

111.151

Figure 8-2.–Electrohydraulic load-sensing governor system, block diagram.

actuator directs oil to or from a remote servo in the valve operator. The valve operator moves the mechanism to increase or decrease the steam, which returns the turbine speed to normal.

The load signal box detects changes in load before they appear as speed changes and applies a proportional voltage to the control box. It detects these changes through the resistor box, which develops a voltage from the secondary of the current transformers. This voltage is compared with the generator load output voltage and, if a difference exists, the load signal box applies a proportional voltage to the control box.

The droop switch allows parallel operation with governors of types other than EG. The circuit breaker auxiliary contact provides a path for control load signals to other paralleled units.

EG-R HYDRAULIC ACTUATOR

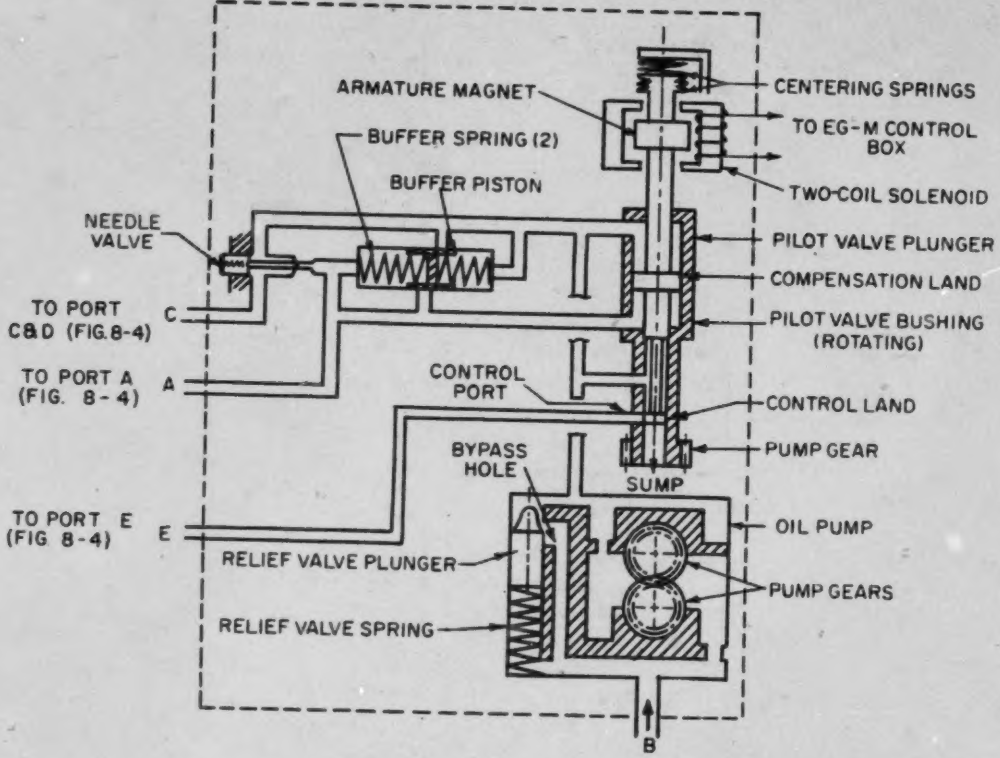
The EG-R hydraulic actuator (fig. 8-3) provides the hydraulic control signal for the valve operator via tubing connections. The signal is controlled by controlling the flow of oil to and from the EG remote servo piston in the valve operator (discussed later).

The actuator receives its electric control signals from the control box as explained previously. The actuator has no self-contained oil sump and receives operating oil from the oil system for the turbine control.

When starting the turbine, you must control the turbine speed manually by using a trip throttle valve (located at the turbine) until an input signal and power become available to the control box. You must manually operate the trip throttle valve because the actuator does not use a centrifugal flywheel head assembly.

If the control signal is lost, or if a faulty control box sends a continuous increase speed signal, the actuator closes the steam valve to shut down the steam supply which trips the turbine off the line.

Since the hydraulic actuator does not have a mechanical speed sensing flywheel head


ARMATURE MAGNET
CENTERING SPRINGS
BUFFER SPRING (2)
TO EG-M CONTROL BOX
BUFFER PISTON
TWO-COIL SOLENOID
NEEDLE VALVE
PILOT VALVE PLUNGER
COMPENSATION LAND
TO PORT C&D (FIG.8-4)
C
PILOT VALVE BUSHING (ROTATING)
TO PORT A (FIG. 8-4)
A
CONTROL PORT
CONTROL LAND
BYPASS HOLE
PUMP GEAR
SUMP
TO PORT E (FIG 8-4)
E
OIL PUMP
RELIEF VALVE PLUNGER
PUMP GEARS
RELIEF VALVE SPRING
B

111.152

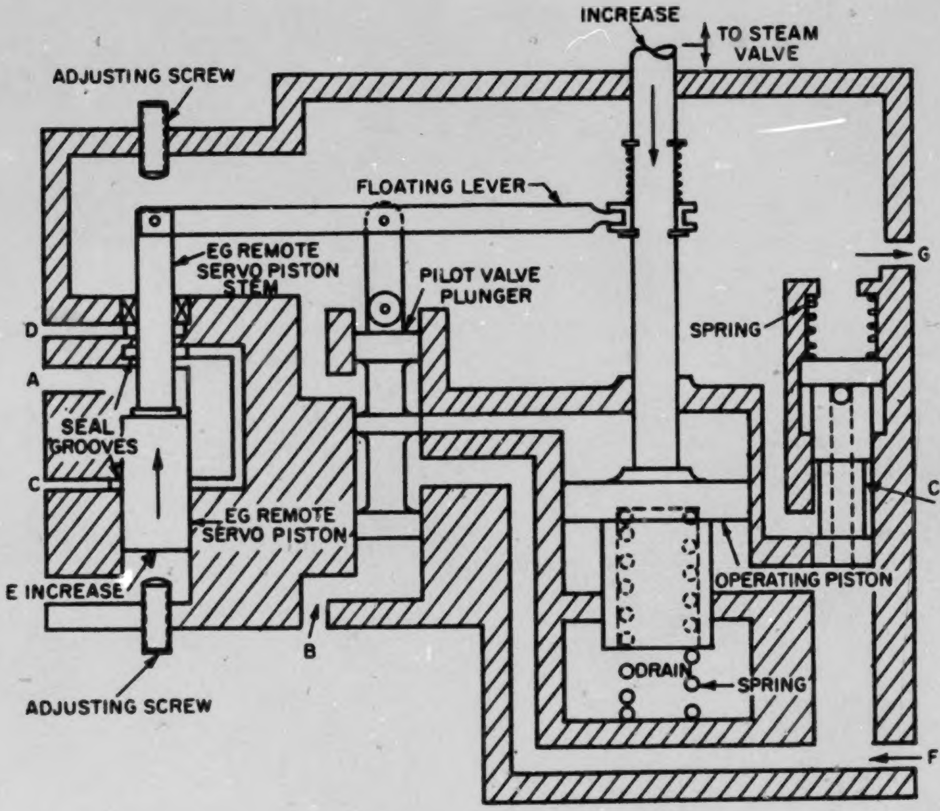
Figure 8-3.—EG-R hydraulic-actuator, mechanical diagram.

assembly, its drive shaft does not have to be driven directly by the turbine. The drive shaft is rotated by a shaft from the gear only to turn the actuator pump gears (fig. 8-3) and to provide relative rotation between the nonrotating pilot-valve plunger and its rotating bushing. The drive shaft is an integral part of the pilot valve bushing. The oil pump of the actuator is designed for drive shaft rotation in one direction only, and the relief valve maintains the operating oil pressure.

Oil from the external supply enters through port B to the oil pump. The pump gears first fill the oil passages and then increase the hydraulic pressure. When the pressure overcomes the force of the relief valve spring, the relief valve plunger is pushed down to uncover the bypass hole; thus, recirculating oil through the pump.

Pressure oil from the pump is supplied to the buffer piston, which constantly applies pressure oil to the top side of the EG remote servo piston (fig. 8-4) through slot A. Pump pressure is applied to the underneath side of the EG remote servo piston through slot E and the pilot valve plunger. The pressure in this hydraulic circuit tends always to move the EG remote servo piston down in the decrease steam direction. However, the EG remote servo piston cannot move down unless the oil trapped between the underneath side of it and the pilot valve plunger can escape to sump.

The pilot valve plunger (fig. 8-3) controls the flow of oil to and from the bottom side of the EG remote servo piston in the valve operator. The pilot valve plunger is connected to an


INCREASE
TO STEAM VALVE
ADJUSTING SCREW
FLOATING LEVER
EG REMOTE SERVO PISTON STEM
PILOT VALVE PLUNGER
G
D
SPRING
A
SEAL GROOVES
C
CUT OUT VALVE
EG REMOTE SERVO PISTON
OPERATING PISTON
E INCREASE
B
DRAIN
SPRING
ADJUSTING SCREW
F

111.153

Figure 8-4.–Valve operator, mechanical diagram.

armature magnet which is spring-suspended in the field of a two-coil solenoid. The output signal from the EG-M control box is applied to the solenoid coils to produce a force (proportional to the current in the coil) which moves the armature magnet and pilot valve plunger up or down. The pilot valve plunger is raised as a result of a decrease in load or a decrease in the speed setting of the control box. It is lowered as a result of an increase in either the load or the control box speed setting. When the electric control signal fades to its onspeed voltage value, the centering springs return the armature magnet and pilot valve plunger to their steady-state, centered positions. The pilot valve plunger is centered when its control land exactly covers the control port in the pilot valve bushing (as shown in fig. 8-3).

With the pilot valve plunger centered, no oil flows to or from the EG remote servo piston. If the pilot valve plunger is raised due to a decrease in load, the oil trapped on the bottom side of the piston is free to escape to sump.

Stability of a system controlled by the electric governor section is enhanced by the use of a temporary negative feedback signal which biases the speed and load signal to the actuator pilot valve plunger. The temporary feedback signal is in the form of a pressure differential applied across the compensating land of the pilot valve plunger. The pressure differential is derived from the buffer system, and is allowed to fade away as the turbine returns to speed.

Movement of the buffer piston to the left partially relieves the compression of the right-hand buffer spring and increases the compression of the left-hand buffer spring. The force of the left-hand buffer spring, tending to resist this movement, results in a slightly higher oil pressure on the right side of the buffer piston than on the left side. The pressure on the left side of the buffer piston is transmitted to the underside of the compensation land of the actuator pilot valve plunger, while the pressure on the right side of the buffer piston is fed to the upperside of the compensation land. The difference in pressures on the two sides of the compensation land produces a force which acts to push the pilot valve plunger back to its centered position.

When the EG remote servo piston has been moved far enough to satisfy the new steam requirement, the force of the pressure differential on the actuator pilot valve plunger will have recentered the actuator pilot valve plunger, even though turbine speed is not yet completely back to normal. The EG remote servo piston movement is thereby stopped as the control box signal returns to its onspeed voltage value. At the same time, the pressure differential on the two sides of the buffer piston (and on the upper and lower sides of the compensating land) is being dissipated by flow of oil through the needle valve orifice. As this occurs, the buffer springs return the buffer piston to its normal (central) position. The decrease in electrical signal to its onspeed value and the dissipation of differential pressure on the two sides of the compensation land occur at the same rate, and the pilot valve remains centered until the turbine is again at the onspeed condition at the decreased load.

When the turbine load increases and the turbine speed decreases, the pilot valve plunger is lowered, and pressure oil flows to the bottom side of the EG remote piston. Because the area on the bottom side of the piston against which the oil pressure acts is greater than the area on the upper side of the piston against which the oil pressure acts, the net force moves the piston upward in the increase steam direction. The oil displaced on the left side of the buffer piston moves the piston to the right, thus causing a pressure differential on the upper and lower sides of the compensation land so that the pilot valve plunger is recentered before turbine speed returns to normal. This pressure differential dissipates through the needle valve orifice, at the same rate at which the electrical signal is reduced, to its onspeed voltage value as the turbine speed returns to normal.

Surrounding the EG remote servo piston and its piston stem (fig. 8-4) are grooves connected to the pump output pressure through port C. These seal grooves have nothing to do with operation of the actuator. They are used to assure that any leakage of pressure oil from the servo comes from a part of the hydraulic circuit where it will do no harm.

VALVE OPERATOR

The valve operator amplifies the hydraulic signals from the hydraulic actuator to provide the high power that is needed to operate the turbine steam valve.

Pressure oil from one side of the actuator buffer system is applied constantly through port A (fig. 8-4) to the upper side of the EG remote servo piston. The actuator pilot valve plunger (fig. 8-3) controls the oil flow through port E to and from the area under the EG remote servo piston. Pressure oil from the governor pump is sent through port C to seal grooves around the EG remote servo piston and piston stem. Port D is for draining leakage oil to sump.

When oil from the hydraulic actuator (through port E) forces the EG remote servo piston upward, the pilot valve plunger is lifted, allowing the pressure oil supply to flow through port F to the top side of the operating piston. Thus the operating piston is forced downward in the increase steam direction. As the operating piston moves downward, the pilot valve plunger is lowered to its centered (null) position (as shown in figure 8-4). This action shuts off the pressure oil flow to the top of the operating piston and stops the movement of the operating piston.

If the EG-R hydraulic actuator pilot valve plunger (fig. 8-4) is raised, any oil under the EG remote servo piston drains out through port E. Then, the pressure oil above the EG remote servo piston pushes the piston downward. At the same time, the pilot valve plunger lowers and the area above the operating valve drains out through port G. The spring force and oil supply pressure on the underside of the operating piston forces the piston upward in the decrease steam direction. As the operating piston moves upward, the pilot valve plunger moves up with it until the plunger reaches its null position and the operating piston movement ceases.

The cutout valve (fig. 8-4) minimizes the amount of manual pumping required to obtain enough oil to open the steam valve to start the turbine. As the supply oil dissipates through port E with the unit shut down, the spring atop the cutout valve pushes the plunger down to open the area under the operating piston to drain through port G. The cutoff valve will lower until it closes off the supply oil path from the underside of the operating piston to port F.

During turbine startup, the starting oil is directed through port B to the underside of the pilot valve plunger, causing it to rise. The manually pumped supply oil pressure (through port F) is considerably less than the normal supply oil and will flow to the upper side of the operating piston, forcing it down (this will also open the steam valve). The operating piston needs only to overcome the force of the spring under it plus any unbalance forces of the steam valve. As the turbine begins to operate, the supply oil pressure through port F will rise. When the supply oil pressure is sufficient to overcome the pressure of the cutoff valve spring, the cutoff valve plunger will rise, enabling normal operation of the valve operator.

The adjusting screws at the top and bottom of the EG remote servo piston limit the direction of piston travel and, through the floating lever, limit the operating piston stroke. The top screw sets the maximum valve limit and the bottom screw sets the shutoff position of the operating piston.

EG-M CONTROL BOX

The control box is designed to provide the control signal to the electrohydraulic transducer in the hydraulic actuator.

As shown in the block diagram of figure 8-5, the control box has three inputs. One is from the load signal box and will be discussed later. The other two are from the PMG and the speed setting (reference) potentiometer.

The input from the PMG is applied to the speed section where it is converted into a d.c. voltage proportional to the speed of the turbine. The reference voltage (speed control) is established by the speed setting potentiometer but is developed internally.

The outputs of the speed section and the speed reference section are compared and, if equal and of opposite polarity, no signal is applied to the amplifier section. If the speed of

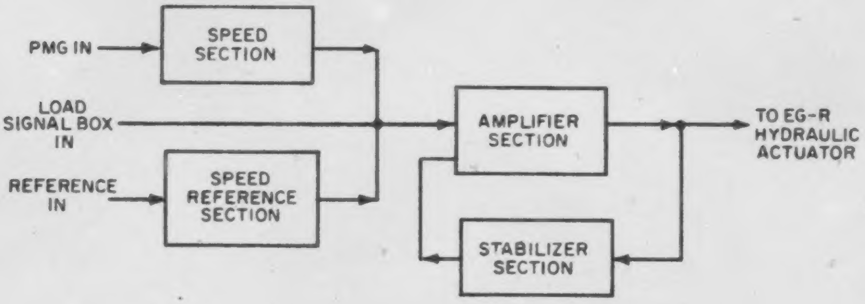


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Figure 8-5.–EG-M control box, block diagram.

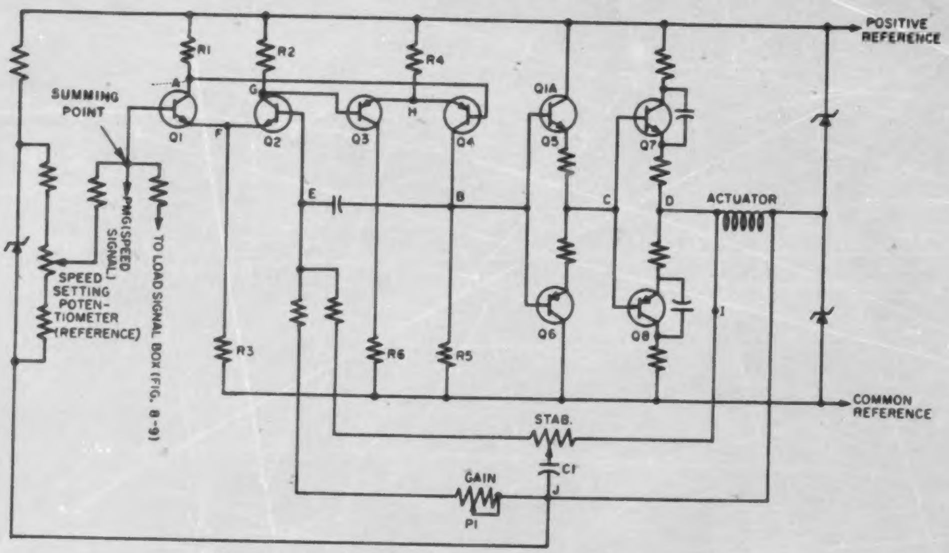

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Figure 8-6.—EG-M control box, simplified schematic.

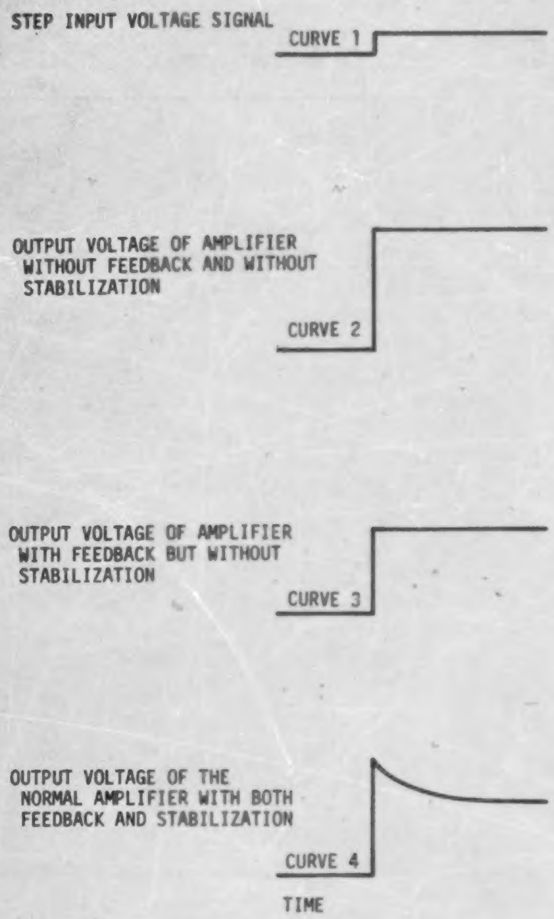
the turbine changes, there is a corresponding change in the signal from the PMG. This causes a change in the output of the speed section and an error voltage is applied to the amplifier section, which is amplified and sent to the hydraulic actuator. Some output is fed back through the stabilizer section to keep the system from overreacting.

The schematic representation of the control box (fig. 8-6) is a simplification of the actual amplifier and is useful in describing its operation.

If the speed setting potentiometer is adjusted to increase speed, it causes a voltage signal change at the base of transistor Q1 in the positive direction. This increases the conduction of transistor Q1, causing increased current through resistor R1 and a drop in potential at point A (base of transistor Q4). The effect on transistor Q4 is to cause an increase in current through resistor R5. The increased voltage drop across resistor R5 raises the potential at point B. An increase in potential at point B (base of transistors Q5 and Q6) causes Q5 to conduct more and Q6 to conduct less which increases the potential at point C (base of transistors Q7 and Q8). This increase causes Q7 to conduct more and Q8 to conduct less which increases the potential at point D. An increase in potential at point D causes current to flow through the actuator coil in the direction to move the actuator pilot valve plunger in the increase steam direction. This steam increase causes the turbine to increase speed. The negative speed signal increase counteracts the previous positive speed signal increase and a new steady state condition of essentially zero voltage is reached both at the summing point and the actuator.

To further explain the function of the amplifier and its stabilizing feedback network, refer to the voltage wave forms of figure 8-7 as well as the schematic of figure 8-6.

Assume that a step input voltage signal is applied to the summing point of the amplifier as shown on curve 1 (fig. 8-7). If the feedback circuit is disconnected at point I (fig. 8-6), the output voltage for this condition (without feedback and stabilization) will be very high as shown in curve 2 (fig. 8-7), and will cause the turbine to hunt excessively. The gain (output voltage divided by input voltage) is very high in this condition. Assume that the feedback network is reconnected at point I, and the stabilizing network is disconnected at point J. In this case the output signal from point D is fed through the stability potentiometer to the base of transistor Q2 (point E) and reduces the amplifier gain. In response to the step input of curve 1, an output voltage for this condition



111.156

Figure 8-7.–Voltage relationships.

(feedback connected but without stabilization) is obtained (curve 3; fig. 8-7).

The gain is reduced in the following sequence. Earlier, we stated that the output voltage at point D and at the actuator increases in response to an increased potential at the summing point of the amplifier. The increase in potential is applied to the base of transistor Q2, causing Q2 to conduct a greater amount, thereby increasing the voltage drop across resistor R3. The potential at point F (the emitter of input transistor Q1), is raised, causing Q1 to conduct less, thereby reducing the amount of voltage drop otherwise experienced at point A. In turn, the amount of conductance of transistor Q4 is reduced. Consequently, there is less voltage change at point B. Adjustment of P1 increases the potential at point E and further reduces the amplifier gain. Transistor Q2 conducts a greater amount thereby reducing the potential at point G because of a greater voltage drop across resistor R2. The potential at G (applied to the base of transistor Q3) causes Q3 to conduct more with a greater voltage drop across resistor R4. Consequently, the lower potential at point H (the emitter of transistor Q4) causes it to conduct less, resulting in less increase in potential at point B, or a gain reduction.

The stabilization signal is obtained through the use of a capacitor. With capacitor C1 disconnected at point J (fig. 8-6), the negative feedback effect reduces the gain (curve 2, fig. 8-7). When the circuit is reconnected at point J, the capacitor temporarily diverts some of the feedback signal away from point E during the charging period of the capacitor.

In response to the input voltage of curve 1 (fig. 8-7), the initial output voltage of the amplifier goes to a high level (curve 4) at the first instant the signal is applied and the feedback signal is varied. As the capacitor charges, the voltage comes down on the curved portion of the line and levels off at approximately the same level as curve 3 when a steady state condition is reached. The shape of curve 4 is determined by an RC time constant and R is adjustable by the stability potentiometer. The normal response of the amplifier to an open loop test (fig. 8-7) produces an output voltage waveform characteristic of curve 4 in response to the input voltage of curve 1.

LOAD SIGNAL BOX

The load signal box enables the governor system to respond to generator load changes as well as to speed changes. Load changes are detected and responded to before they appear as turbine speed changes, thereby minimizing change transients.

The load signal box (fig. 8-8) converts a three-phase input signal (from the generator leads through the resistor box) to a d.c. voltage which is proportional to the KW load on the generator. The voltage is applied to the load pulse section and the paralleling network used with single generator or paralleled with other similar EG governors. When operated with dissimilar governors, the droop and load pulse sections are used. The droop switch determines operating mode for which the system is set up.

Single Generator Operation

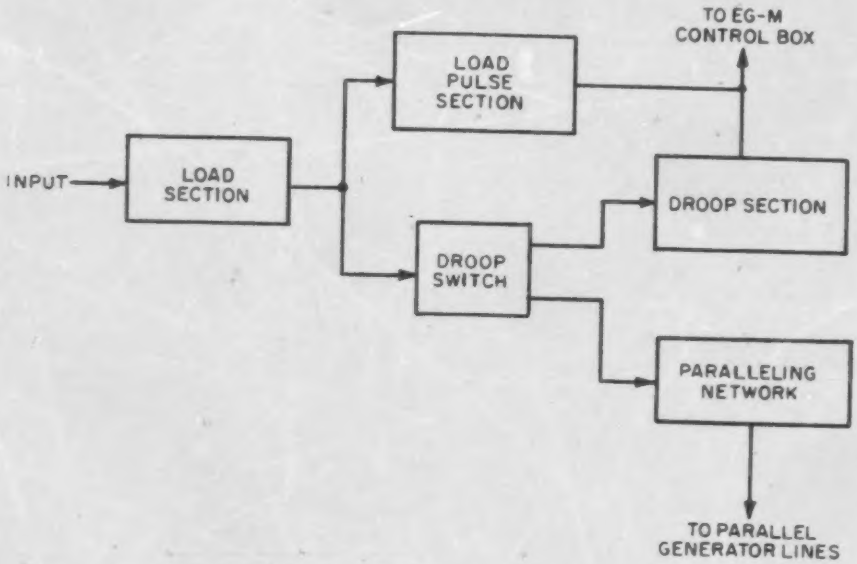
Look at the simplified schematic of the load signal box in figure 8-9. Input signals for the load signal box are taken from the secondary of the generator current transformers and developed in the resistor box. The resistor box contains three resistors (one for each phase). The voltage input is applied to transformer T2 and compared to the generator voltage phase (which is taken from the generator line, stepped down, and applied to transformer T1). If both voltages are in phase, they will cancel and no output will appear. But if they are out of phase (the load is changing), a voltage in proportion to the generator load will be rectified by CR1 and CR2. (Although only one phase is shown in figure 8-9, each phase is compared and the comparison circuitry is identical to that shown.)

The amplitude of the signal can be varied by the GAIN ADJ. potentiometer. A variable pulse output is developed by the charge/discharge time of C1 through the LOAD PULSE ADJ. potentiometer.

The load pulse signal is initially maximum and gradually decreases to zero. Figure 8-10 represents load pulse signals in response to load changes. The signal is of the proper polarity to set the steam valve in the right direction to compensate for the change. The output signal is applied to the summing point in the EG-M control box (fig. 8-6).

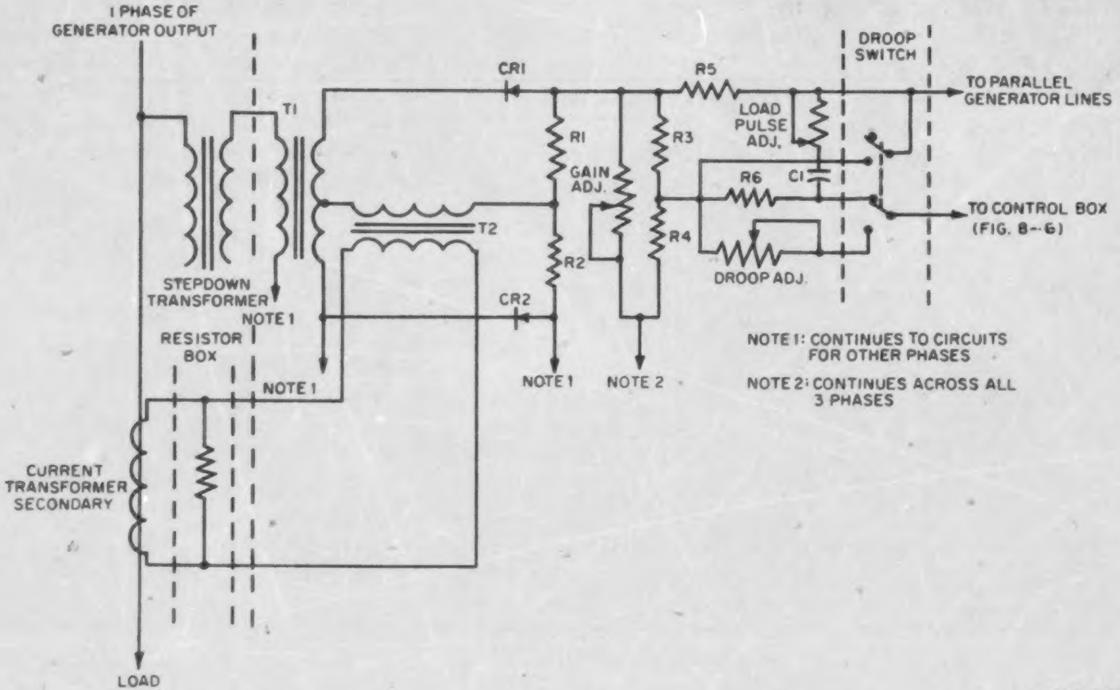
Parallel Operation with Other EG Governor Systems

When the load signal box is used with other EG governor systems, the operation is the same



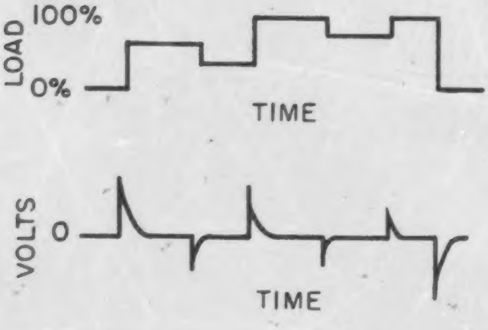
111.157

Figure 8-8.—Load signal box, block diagram.


I PHASE OF GENERATOR OUTPUT
T1
CR1
R5
DROOP SWITCH
TO PARALLEL GENERATOR LINES
R1
R3
LOAD PULSE ADJ.
GAIN ADJ.
R6
C1
TO CONTROL BOX (FIG. 8-6)
T2
R4
R2
DROOP ADJ.
STEPDOWN TRANSFORMER
NOTE 1
CR2
RESISTOR BOX
NOTE 1
NOTE 1
NOTE 2
NOTE 1: CONTINUES TO CIRCUITS FOR OTHER PHASES
NOTE 2: CONTINUES ACROSS ALL 3 PHASES
CURRENT TRANSFORMER SECONDARY
LOAD

111.158

Figure 8-9.—Load signal box, simplified schematic.



111.159

Figure 8-10.—Comparison of load pulse signals to load changes.

as for single operation (fig. 8-9) except for a closed circuit breaker (not shown). The closed circuit breaker connects the paralleling lines to enable the load signal box to provide the same signal information to the control box of all the parallel units.

Parallel Operation with Dissimilar Type Governor Systems

For operation with dissimilar type governor systems, the droop switch must be turned on (down position in fig. 8-9). This shorts out the paralleling lines so that the parallel units are effectively not connected to the load signal box. The signal to the control box is fed via the DROOP ADJ. potentiometer. This adjustment compensates for differences in generator ratings and the reactive load carried by them.

MAINTENANCE

Governor faults are usually revealed in turbine speed variations. However, a check of the system is necessary since not all speed variations are caused by a faulty governor.

Check first to determine that the changes are not a transient result of load changes. If the load is constant, hold an inspection to see that the operating linkage between the hydraulic actuator and the turbine is free from binding or lost motions. If the linkage is proper, check the voltage regulator for proper operation. If these checks do not reveal the cause of the speed variation, the governor is probably faulty.

In troubleshooting the governor system, first check the voltage across the input to the hydraulic actuator with the system running on speed and set for single operation. If the voltage is not correct (+0.5 Vdc to -0.5 Vdc) and cannot be set within range by the centering screw in the actuator, or if the voltage fluctuates more than ±0.25 Vdc and cannot be stilled by the GAIN ADJ. or the STAB. ADJ., the control box may be defective.

To bench test the control box, disconnect it from the load signal box, use a 3-phase power supply instead of the normal supply, instead of the speed signal apply a frequency oscillator output signal set to the rated speed frequency of the PMG (fig. 8-6), and use a resistive load instead of the actuator. If an oscillator is not available, you can manually control the turbine-generator set to provide the PMG signal.

The converter section is working properly if (after removing the amplifier section) the voltage at the collector of Q2 (fig. 8-6) is correct (6 Vdc at rated speed). If this is correct, place the amplifier back in the circuit. The voltage across the resistive load should be about zero volts. If not, the amplifier section is faulty.

If the trouble is a change in unit steady state speed as the load is changed, check the voltage across the actuator input under different load conditions. If the voltage is the same at both loads, the control box may be defective. If the voltages differ by more than 0.2 Vdc, the actuator is probably faulty.

The sources of most troubles in the hydraulic actuator or valve operator is dirty oil. Grit and other impurities may be introduced into the system with the oil or may form when the oil begins to break down (oxidize) or become sludge. The moving parts within the actuator and valve operator are continually lubricated by the oil within the units. Thus, grit and other impurities can cause excessive wear of valves, pistons, and plungers, and can cause these parts to stick or freeze in their bores.

CHAPTER 9

ENGINEERING CASUALTY CONTROL

The operating efficiency of a ship depends largely on the ability of the Engineering Department to continue its services both during normal operations and during casualty to any part of the ship. Engineering casualty control is concerned with the prevention, minimization, and correction of the effects of operational and battle casualties as outlined in chapter 9882 of *NavShips Technical Manual*.

In this chapter we shall discuss the broad aspects of engineering casualty control, including casualties to the machinery; electrical, and piping installations aboard ship. The text and illustrations are based on DD445/692/710 class destroyers. Refer to the *Casualty Control Manual* prepared by the type commander for details concerning engineering casualty control instructions for your class ship.

Although an Electrician's Mate is not responsible for machinery other than that driven by electric power, you should have a general knowledge of the main propulsion and auxiliary plants to help you acquire a better understanding of the overall system.

MISSION OF CASUALTY CONTROL

The mission of casualty control is to maintain all engineering services in a state of maximum reliability under all conditions of operation. Failure to provide all normal services will decrease the ship's effectiveness as a fighting unit, either directly by reducing its mobility or its offensive and defensive power (including the ability to control fire, flooding, and hull or armament damage), or indirectly by reducing habitability and thus, personnel morale and efficiency. Casualty control can be divided into three phases: prevention, correction, and restoration.

CASUALTY PREVENTION

Casualty prevention is the most effective phase of casualty control. It concerns the quality of preventive maintenance on machinery and systems as an effort toward counteracting the effects of operational and battle casualties. Proper preventive maintenance will greatly reduce the occurrence of casualties caused by material failures. Continuous detailed inspection procedures are necessary not only to disclose partially damaged parts that may fail at a critical time, but also to eliminate the underlying conditions, including maladjustment, improper lubrication, and corrosion, which are detrimental to machinery and cause early failure.

CASUALTY CORRECTION

Casualty correction concerns the correction of the effects of operational and battle damage to minimize the effect on the mobility and offensive and defensive power of the ship. This phase consists of the action taken at the time of the casualty to prevent future damage to the affected unit and to prevent the casualty from spreading through secondary effects.

The speed with which corrective action is applied to an engineering casualty is often of paramount importance. The extent of the damage must be thoroughly investigated and reported to the engineer officer. To maintain maximum available speed and services, the engineer officer must be informed at all times of the condition of his plant.

The commanding officer has the responsibility of deciding whether to continue operation of equipment under casualty conditions with the possible risk of permanent damage. Such action can be justified only when the risk of even greater damage or loss of the ship may be incurred by immediately securing the affected unit.

CASUALTY RESTORATION

Casualty restoration concerns making the necessary repairs to completely restore the installation to its original condition.

If damage to equipment cannot be repaired by the repair facilities of the forces afloat, the ship will probably be sent to a naval shipyard before returning to service. In this case, the salvage efforts of the crew must ensure that no additional deterioration of equipment will occur between the time of beginning operations after the casualty and arrival at the yard.

ENGINEERING CONDITIONS OF READINESS

The purpose of engineering conditions of readiness is to establish standards of material readiness in the engineering department for the various conditions of operation of the main propulsion units and auxiliary machinery. The required engineering conditions of readiness are conditions 1 through 4.

MAIN PROPULSION UNITS

The factors that determine the readiness condition of the main plant are the number of boilers in use and the standby condition of the remaining boilers, and whether the main plant is split or cross-connected. The four readiness conditions are defined in terms of these factors for DD692 class destroyers:

CONDITION 1 utilizes four boilers with the main plant split. Boilers 1 and 3 supply auxiliary steam to the starboard lines, and boilers 2 and 4 supply auxiliary steam to the port lines. This condition of readiness must be used at general quarters. On ships having both electric and steam pumps, the steam pumps should be used with the electric pumps lined up in standby condition.

CONDITION 2 utilizes two boilers with the main plant split. The remaining two boilers should be boosted to assure readiness within 1 hour. This condition of readiness should be used in a war zone when attack is probable.

CONDITION 3 utilizes two boilers with the remaining boilers secured but completely operational within 2 hours. The main plant can be split or cross-connected to conform with security requirements. However, the main plant should be split under war conditions, when entering or leaving port, or when steaming in restricted waters and in heavy weather.

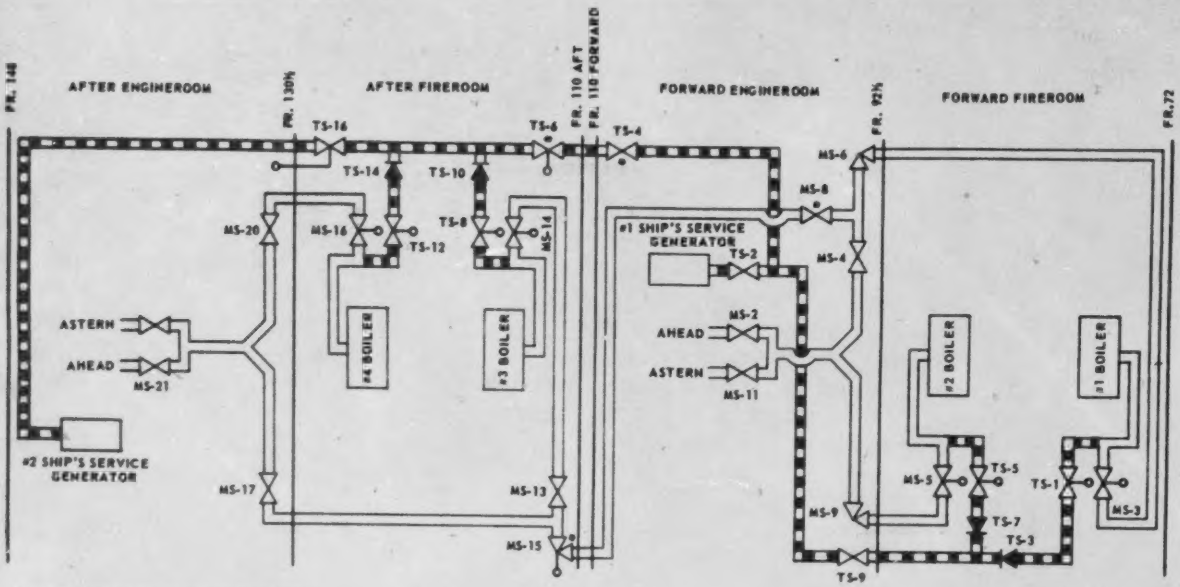
CONDITION 4 utilizes boiler and turbine combinations for the best fuel economy to conform with operational requirements. The remaining boilers should be available within 8 hours.

The main and auxiliary steam systems are shown in figures 9-1 and 9-2.

AUXILIARY MACHINERY

The readiness of auxiliary machinery is determined by the requirements of the turbogenerators, diesel generators, refrigeration plant, and the main drain system for the various conditions of readiness. The classification of valves and fittings in the auxiliary systems for setting material conditions is contained in the *Damage Control Book*.

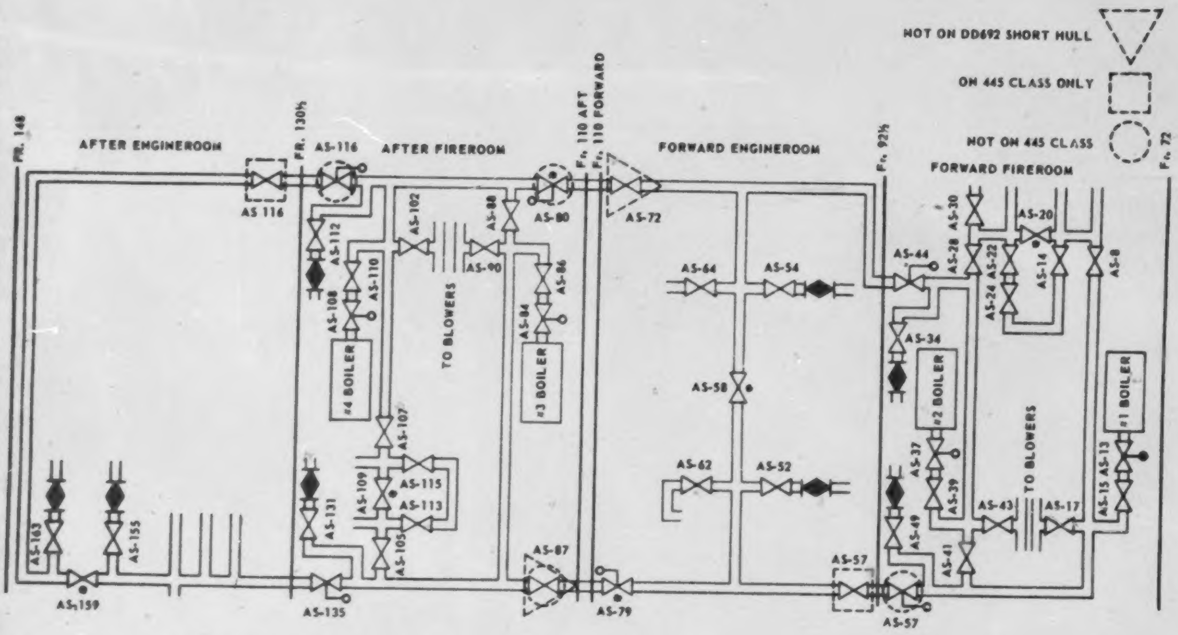
Both TURBOGENERATORS should be used with the electrical load split when in condition 1 or condition 2, and under circumstances when split plant is required in condition 3. In condition 1 both turbogenerators should exhaust to their auxiliary condensers. When both generators are in use during general quarters and battle


FR. 148
AFTER ENGINEROOM
FR. 130½
AFTER FIREROOM
FR. 110 AFT
FR. 110 FORWARD
FORWARD ENGINEROOM
FR. 92½
FORWARD FIREROOM
FR.72
TS-16
TS-6
TS-4
TS-14
TS-10
MS-6
MS-8
MS-20
MS-16
TS-12
TS-8
MS-14
#1 SHIP'S SERVICE GENERATOR
TS-2
MS-4
MS-2
AHEAD
ASTERN
MS-11
ASTERN
AHEAD
MS-21
#4 BOILER
#3 BOILER
#2 BOILER
#1 BOILER
#2 SHIP'S SERVICE GENERATOR
MS-17
MS-13
MS-5
TS-5
TS-1
MS-9
TS-7
MS-3
TS-3
MS-15
TS-9

* CLOSED DURING SPLIT PLANT OPERATION

Figure 9-1.–Main steam system.

111.55


NOT ON DD692 SHORT HULL
ON 445 CLASS ONLY
NOT ON 445 CLASS
FR. 148
AFTER ENGINEROOM
FR. 130½
AS-116
AFTER FIREROOM
Fr. 110 AFT
Fr. 110 FORWARD
FORWARD ENGINEROOM
Fr. 92½
FORWARD FIREROOM
Fr. 72
AS 116
AS-112
AS-110
AS-108
AS-102
AS-90
AS-88
AS-80
AS-86
AS-84
AS-72
TO BLOWERS
#4 BOILER
#3 BOILER
AS-64
AS-54
AS-44
AS-30
AS-28
AS-24
AS-22
AS-20
AS-14
AS-8
AS-34
#2 BOILER
#1 BOILER
AS-58
AS-107
AS-109
AS-115
AS-113
AS-105
AS-131
AS-62
AS-52
AS-37
AS-39
TO BLOWERS
AS-15
AS-13
AS-163
AS-155
AS-43
AS-17
AS-87
AS-57
AS-49
AS-41
AS-159
AS-135
AS-79
AS-57

* CLOSED DURING SPLIT PLANT OPERATION

Figure 9-2.–Auxiliary steam system.

111.56

conditions, the electrical load should be split by opening the a.c. and d.c. bus-tie circuit breakers on both the forward and after ship's service switchboards.

The DIESEL GENERATORS should be set up for full automatic operation at all times except when receiving shore power. The fully automatic operational condition of the diesel generators should be maintained during nuclear, biological, or chemical operations. Positive ventilation must be assured to the diesel generator rooms during these operations. Blowers should be turned off, but vent ducts can remain open to prevent suffocation of personnel when the diesel engine starts. Personnel in these spaces are required to wear gas masks and protective clothing.

The REFRIGERATION PLANT should be secured for condition 1 and reenergized as necessary to preserve food. Salt water supply valves to the refrigeration condensers should be classified, red circle Z.

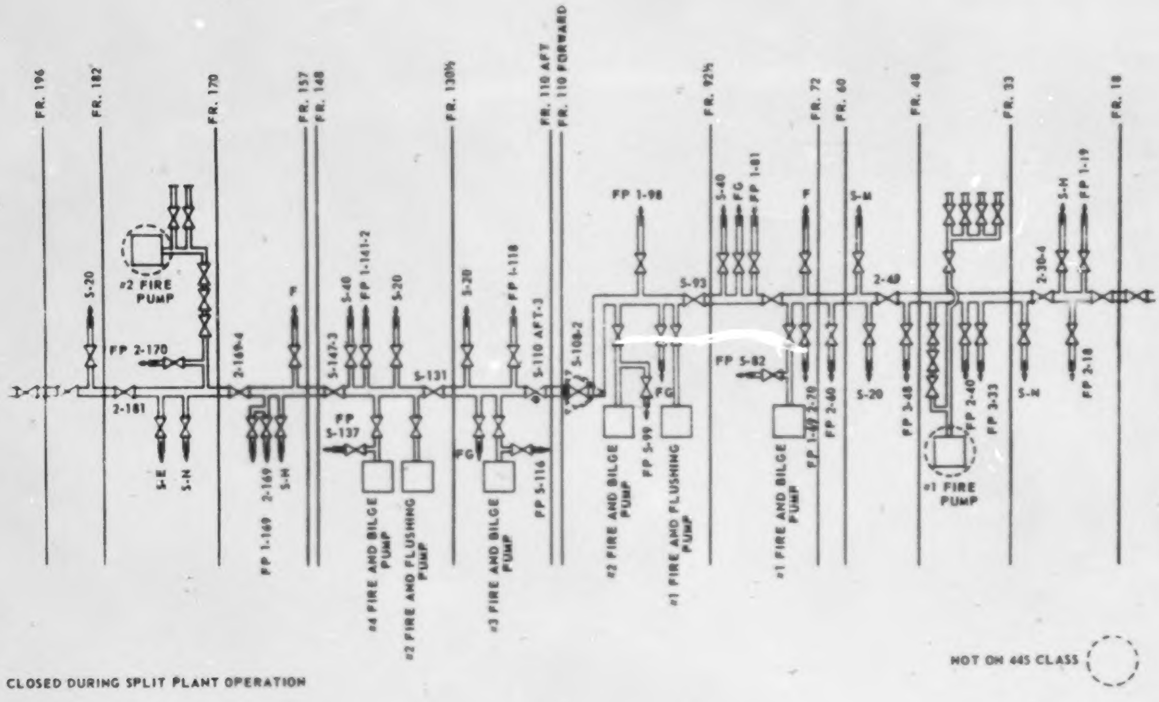
The MAIN DRAIN SYSTEM for condition 1 consists of lining up fire and bilge pumps 1 and 3 (forward and after firerooms) to discharge to the firemains (fig. 9-3).

Fire and bilge pumps 2 and 4 (forward and after enginerooms) are turning over slowly on sea suction and discharging to the sea. In this condition the pumps can be placed rapidly on the firemain or bilge suctions.

The bilge suction valves in each space should be left open at all times, especially for condition 1. Bulkhead cutout valves should be closed except when pumping on an adjacent space.

CASUALTY CONTROL ORGANIZATION

The speed with which corrective action is applied to an engineering casualty depends on


FR. 196
FR. 182
FR. 170
FR. 157
FR. 148
FR. 130½
FR. 110 AFT
FR. 110 FORWARD
FR. 92½
FR. 72
FR. 60
FR. 48
FR. 33
FR. 18
S-20
#2 FIRE PUMP
FP 2-170
2-181
S-E
S-N
2-169-4
FP 1-169
2-169
S-N
F
S-147-3
S-40
FP 1-141-2
S-20
FP S-137
#4 FIRE AND BILGE PUMP
#2 FIRE AND FLUSHING PUMP
S-131
S-20
FG
#3 FIRE AND BILGE PUMP
FP 1-118
S-110 AFT-3
FP S-116
S-108-2
FP 1-98
#2 FIRE AND BILGE PUMP
FP S-99
FG
#1 FIRE AND FLUSHING PUMP
S-93
S-40
FG
FP 1-81
FP S-82
#1 FIRE AND BILGE PUMP
F
FP 1-69
2-70
FP 2-60
S-M
S-20
2-48
FP 3-48
#1 FIRE PUMP
FP 2-40
FP 3-33
S-N
2-30-4
S-M
FP 1-19
FP 2-18
CLOSED DURING SPLIT PLANT OPERATION
NOT ON 445 CLASS

111.57

Figure 9-3.—Firemain system.

effective personnel organization and constant training.

WATCH TEAMS

The basic organization for engineering casualty control is the watch team in each machinery space. Three watches are required for each of the steaming spaces.

The watch teams should be thoroughly organized with each man assigned his duties for watch standing, including each casualty control procedure, fire, flooding, and setting of material conditions. The petty officer in charge of each team should maintain complete control to avoid confusion, which could disrupt the organization and coordination of his team.

Dissemination of information to all stations is extremely important in effectively controlling engineering casualties. It is essential that the engineer officer receive brief, clear, and concise information from all stations to properly administer the operation of the engineering plant and to promptly order corrective measures for the control of casualties.

The sound-powered telephone (circuit 2JV) is the principal means of transmitting engineering casualty information efficiently. The telephone talker has an important job. He is the key to good communications. If a message is not relayed promptly and correctly, it may place the ship in danger. In battle, the safety of the ship and the crew depends on how well the talker uses his voice and equipment. The importance of officers and petty officers being proficient in using proper engineering terms and phraseology cannot be overstressed. It is not the responsibility of the talker to decipher, translate, or rephrase improperly transmitted orders. This is the responsibility of the person issuing the order or originating the message. It is the duty of the talker to relay the message as given.

Casualty Control Phraseology

Standard phraseology greatly enhances communications both within and between teams. It minimizes confusion by reducing the amount of conversation so that transmissions are easily relayed and understood. When practicable, one command should initiate a whole casualty procedure. It is much more effective within the team and between teams to pass the command, "cross-connect the plant," or "cross-connect main feed port side," than "open valves main steam 15, main steam 8, auxiliary steam 79 and 80, auxiliary 44, and so on."

If the command from main engine control is "cross-connect main feed starboard side," the petty officers in charge of No. 1 and No. 2 firerooms will repeat "cross-connect main feed starboard side." The men already assigned this procedure will open valves, MF-3 and MF-37 (fig. 9-4), with no further command. The men should report back when a job is done because the engineer officer often has to wait for a report before giving another command. The use of good talker procedure and standard phraseology will show immediate results.

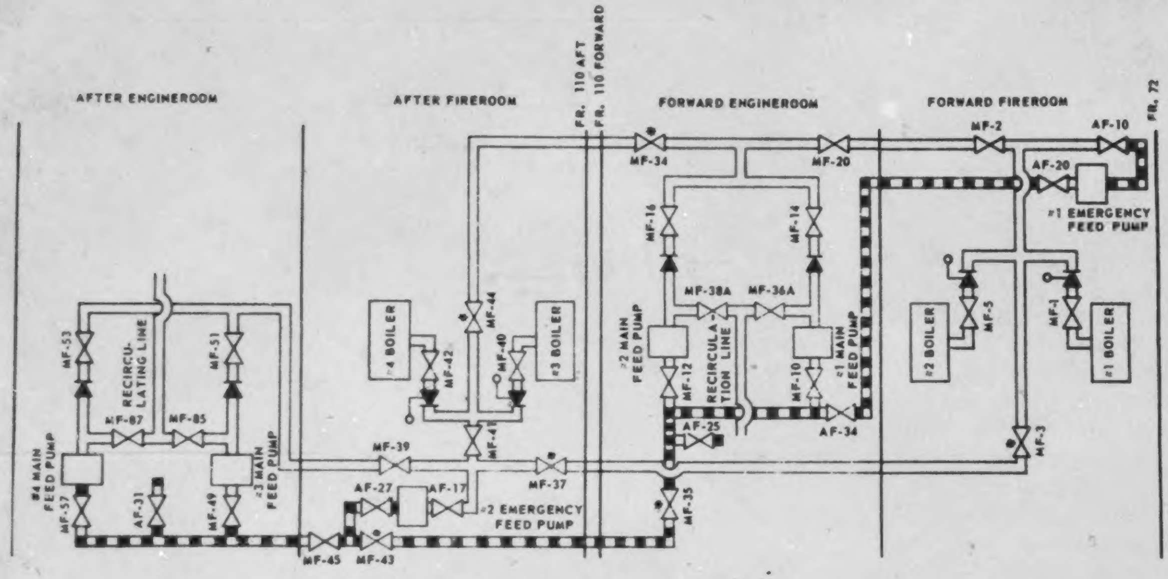
CASUALTY CONTROL BOARD

The casualty control board (fig. 9-5) is essential to effective casualty control during battle conditions. It furnishes a complete picture of the machinery available to the engineer officer at general quarters and watch personnel during condition watches.

For optimum results, a casualty control board should be installed at the main engine control, the after engineroom, and at the main propulsion repair party station. The 2JV talkers at these stations should be responsible for maintaining the boards. The status of machinery is indicated by marking the affected unit with a grease pencil on the plexiglass front of the casualty control board.

PROPULSION REPAIR PARTY

The engineering casualty control organization also includes the propulsion repair party, which is integrated into repair 5 (propulsion repair station). The personnel assigned should be specialists in main propulsion operation and repair as well as highly skilled in the overall field of damage and casualty control. Repair 5 should be organized to facilitate


AFTER ENGINEROOM
AFTER FIREROOM
FR. 110 AFT
FR. 110 FORWARD
FORWARD ENGINEROOM
FORWARD FIREROOM
FR. 72
MF-53
RECIRCU-LATING LINE
MF-51
MF-87
MF-85
#4 MAIN FEED PUMP
#3 MAIN FEED PUMP
MF-57
AF-31
MF-49
MF-45
MF-43
#4 BOILER
#3 BOILER
MF-42
MF-44
MF-40
MF-41
MF-39
MF-37
AF-27
AF-17
#2 EMERGENCY FEED PUMP
MF-34
MF-20
MF-16
MF-14
MF-38A
MF-36A
#2 MAIN FEED PUMP
#1 MAIN FEED PUMP
MF-12
RECIRCULA-TION LINE
MF-10
AF-25
AF-34
MF-35
MF-2
AF-10
AF-20
#1 EMERGENCY FEED PUMP
#2 BOILER
MF-5
MF-1
#1 BOILER
MF-3

* CLOSED DURING SPLIT PLANT OPERATION

111.58

Figure 9-4.—Main feed system.

immediate securing of any or all propulsion spaces; to effect repairs to any steam piping or equipment; to station an underway watch and relieve the general quarters team in any propulsion space; and to evaluate and control any casualty or damage in that section of the ship for which it (repair 5) is responsible.

Personnel assigned to repair 5 aboard a destroyer with a full personnel complement consist of an Electrical Officer (normally a junior officer); 1 MMC and 1 MM2 (Machinery Repair); 1 BTC and 1 BT of any pay grade (Boiler Repair); 1 MM or MR of any pay grade (Auxiliary Repair); 1 EMC or EM1 (Electrical Repair ; 1 MMFA and 1 BTFA (Stretcher Bearers); 1 MM3 or MMFN (2JZ Talker); 1 MM3 or MMFN (2JV Talker); and 1 BTFA (Messenger).

In the event of damage requiring the abandonment of any machinery space, personnel abandoning the space should report to the officer in charge of repair 5 for assignment to duty.

The relationship between repair 5 and other repair parties appears in *Military Requirements for Petty Officers 3 & 2*, NAVEDTRA 10056-C.

Electrical Officer is in charge of the propulsion repair station. He is the evaluator, coordinator, and the relief for the officer-in-charge of main propulsion.

Machinery Repair (MMC) is in charge of securing engineroom spaces and in effecting engineroom and auxiliary repairs. He is the relief for the CPO of the watch. The MM2 assists in securing engineroom spaces and in effecting engineroom and auxiliary repairs. He is the relief for the engineroom lower-level watch.

Boiler Repair (BTC) is in charge of securing fireroom spaces and in effecting fireroom repairs. He is the relief for the BT of the watch. The BT (any pay grade) assists in securing fireroom spaces and in effecting fireroom repairs. He is the relief for the checkman.

Auxiliary Repair (MM or MR any pay grade) assists in securing engineroom spaces and auxiliary machinery and in effecting engineroom

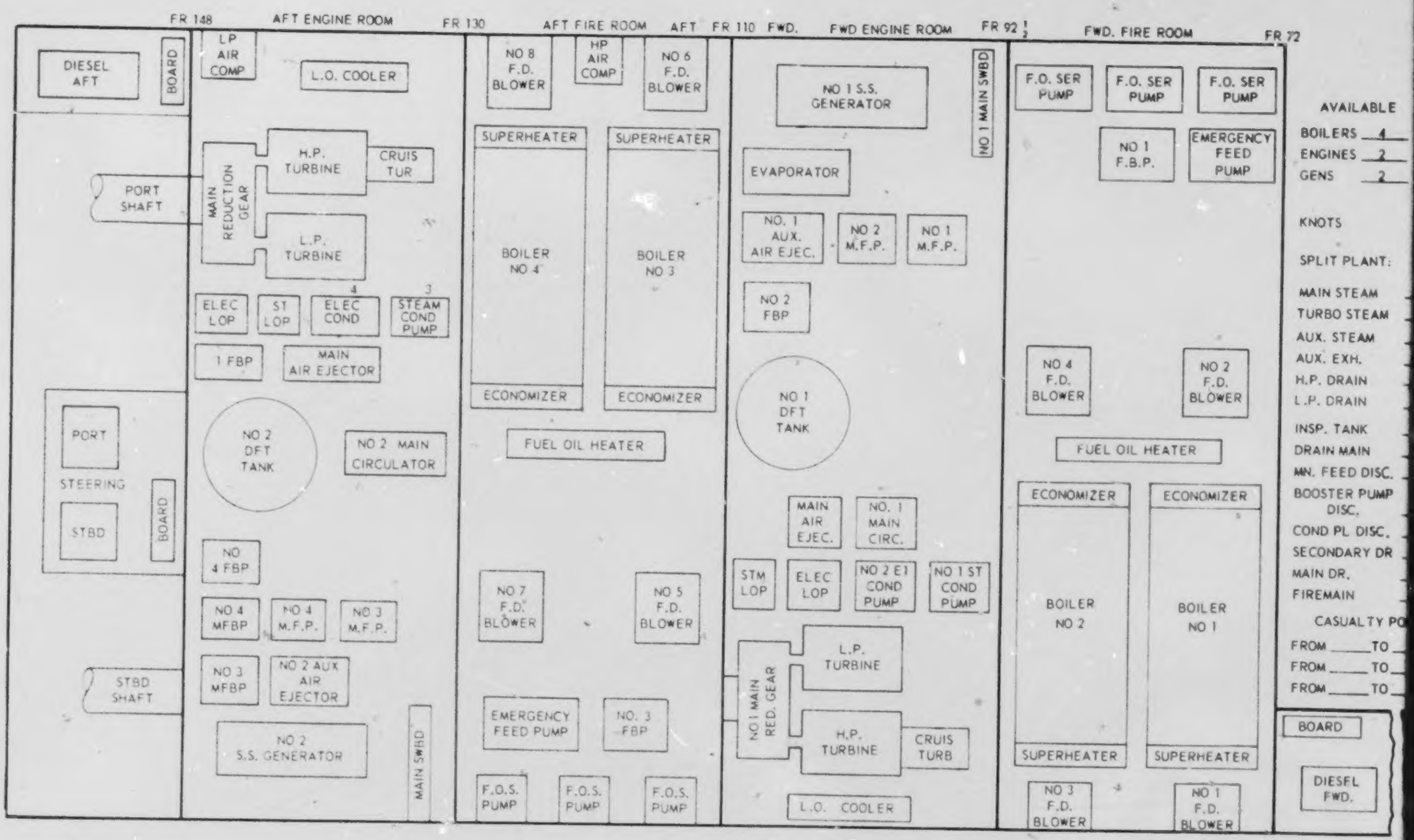

FR 148
AFT ENGINE ROOM
FR 130
AFT FIRE ROOM
AFT
FR 110
FWD.
FWD ENGINE ROOM
FR 92 1/2
FWD. FIRE ROOM
FR 72
DIESEL AFT
BOARD
LP AIR COMP
L.O. COOLER
PORT SHAFT
MAIN REDUCTION GEAR
H.P. TURBINE
CRUIS TUR
L.P. TURBINE
ELEC LOP
ST LOP
4
ELEC COND
3
STEAM COND PUMP
1 FBP
MAIN AIR EJECTOR
PORT
STEERING
STBD
BOARD
NO 2 DFT TANK
NO 2 MAIN CIRCULATOR
NO 4 FBP
NO 4 MFBP
NO 4 M.F.P.
NO 3 M.F.P.
NO 3 MFBP
NO 2 AUX AIR EJECTOR
STBD SHAFT
NO 2 S.S. GENERATOR
MAIN SWBD
NO 8 F.D. BLOWER
HP AIR COMP
NO 6 F.D. BLOWER
SUPERHEATER
SUPERHEATER
BOILER NO 4
BOILER NO 3
ECONOMIZER
ECONOMIZER
FUEL OIL HEATER
NO 7 F.D. BLOWER
NO 5 F.D. BLOWER
EMERGENCY FEED PUMP
NO. 3 FBP
F.O.S. PUMP
F.O.S. PUMP
F.O.S. PUMP
NO 1 S.S. GENERATOR
NO 1 MAIN SWBD
EVAPORATOR
NO. 1 AUX. AIR EJEC.
NO 2 M.F.P.
NO 1 M.F.P.
NO 2 FBP
NO 1 DFT TANK
MAIN AIR EJEC.
NO. 1 MAIN CIRC.
STM LOP
ELEC LOP
NO 2 E1 COND PUMP
NO 1 ST COND PUMP
NO 1 MAIN RED. GEAR
L.P. TURBINE
H.P. TURBINE
CRUIS TURB
L.O. COOLER
F.O. SER PUMP
F.O. SER PUMP
F.O. SER PUMP
NO 1 F.B.P.
EMERGENCY FEED PUMP
NO 4 F.D. BLOWER
NO 2 F.D. BLOWER
FUEL OIL HEATER
ECONOMIZER
ECONOMIZER
BOILER NO 2
BOILER NO 1
SUPERHEATER
SUPERHEATER
NO 3 F.D. BLOWER
NO 1 F.D. BLOWER
AVAILABLE
BOILERS 4
ENGINES 2
GENS 2
KNOTS
SPLIT PLANT:
MAIN STEAM
TURBO STEAM
AUX. STEAM
AUX. EXH.
H.P. DRAIN
L.P. DRAIN
INSP. TANK
DRAIN MAIN
MN. FEED DISC.
BOOSTER PUMP DISC.
COND PL DISC.
SECONDARY DR
MAIN DR.
FIREMAIN
CASUALTY PO
FROM ____ TO
FROM ____ TO
FROM ____ TO
BOARD
DIESEL FWD.

Figure 9-5.—Casualty control board.

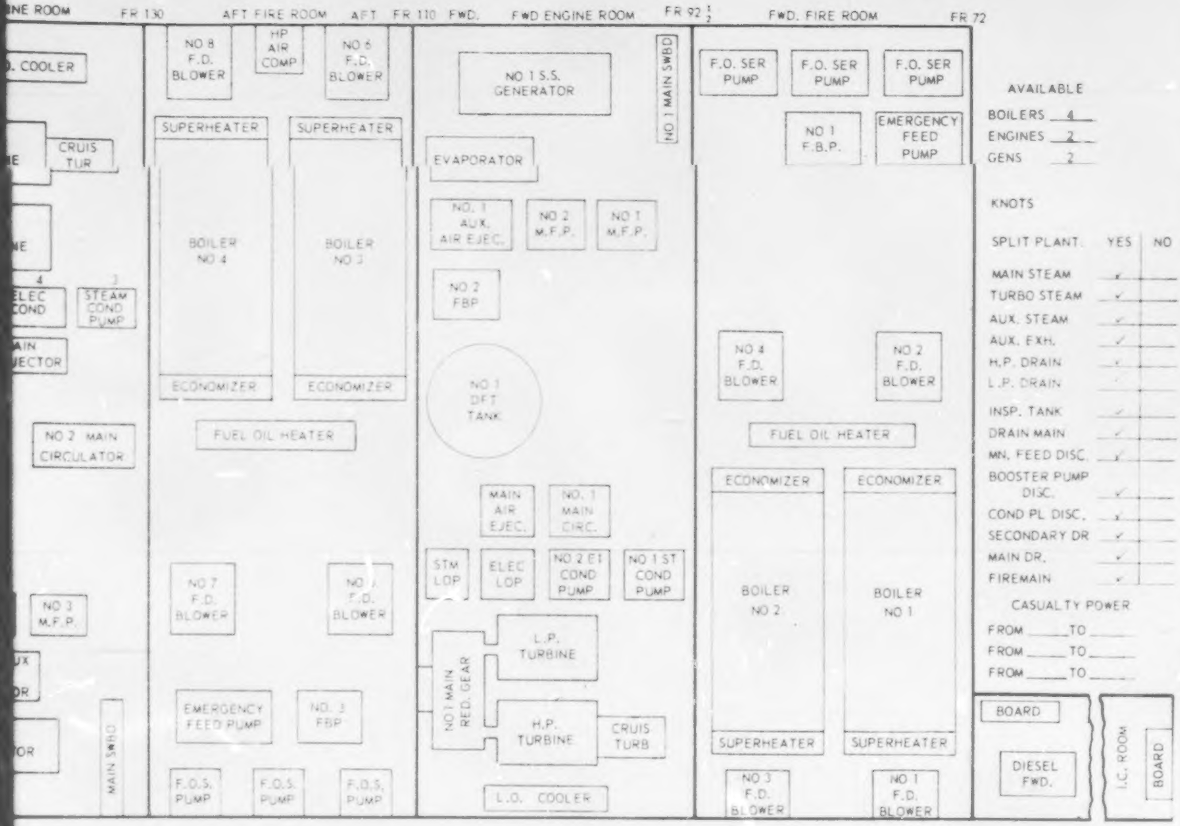

INE ROOM
FR 130
AFT FIRE ROOM
AFT
FR 110
FWD.
FWD ENGINE ROOM
FR 92 ½
FWD. FIRE ROOM
FR 72
. COOLER
NO 8 F.D. BLOWER
HP AIR COMP
NO 6 F.D. BLOWER
NO 1 S.S. GENERATOR
NO 1 MAIN SWBD
F.O. SER PUMP
F.O. SER PUMP
F.O. SER PUMP
SUPERHEATER
SUPERHEATER
EVAPORATOR
NO 1 F.B.P.
EMERGENCY FEED PUMP
CRUIS TUR
NE
NE
BOILER NO 4
BOILER NO 3
NO. 1 AUX. AIR EJEC.
NO 2 M.F.P.
NO 1 M.F.P.
ELEC COND
STEAM COND PUMP
NO 2 FBP
AIN JECTOR
NO 1 DFT TANK
NO 4 F.D. BLOWER
NO 2 F.D. BLOWER
ECONOMIZER
ECONOMIZER
NO 2 MAIN CIRCULATOR
FUEL OIL HEATER
FUEL OIL HEATER
ECONOMIZER
ECONOMIZER
MAIN AIR EJEC.
NO. 1 MAIN CIRC.
STM LOP
ELEC LOP
NO 2 EL COND PUMP
NO 1 ST COND PUMP
NO 7 F.D. BLOWER
NO 5 F.D. BLOWER
NO 3 M.F.P.
BOILER NO 2
BOILER NO 1
UX
OR
L.P. TURBINE
NO 1 MAIN RED. GEAR
EMERGENCY FEED PUMP
NO. 3 FBP
H.P. TURBINE
CRUIS TURB
OR
MAIN SWBD
SUPERHEATER
SUPERHEATER
F.O.S. PUMP
F.O.S. PUMP
F.O.S. PUMP
L.O. COOLER
NO 3 F.D. BLOWER
NO 1 F.D. BLOWER
AVAILABLE
BOILERS 4
ENGINES 2
GENS 2
KNOTS
SPLIT PLANT
YES
NO
MAIN STEAM ✓
TURBO STEAM ✓
AUX. STEAM ✓
AUX. EXH. ✓
H.P. DRAIN ✓
L.P. DRAIN ✓
INSP. TANK ✓
DRAIN MAIN ✓
MN. FEED DISC. ✓
BOOSTER PUMP DISC. ✓
COND PL DISC. ✓
SECONDARY DR ✓
MAIN DR. ✓
FIREMAIN ✓
CASUALTY POWER
FROM ____ TO ____
FROM ____ TO ____
FROM ____ TO ____
BOARD
DIESEL FWD.
I.C. ROOM
BOARD

Figure 9-5.—Casualty control board.

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and auxiliary repairs. He is the relief for the throttleman.

Electrical Repair (EMC or EM1) is in charge of securing electrical power and circuits, rigging casualty power in the main propulsion spaces, and in effecting electrical repairs. He is the relief for the electrical switchboard watch.

Stretcher Bearer (MMFA) assists in securing engineroom spaces and in effecting engineroom and auxiliary repairs. He is the relief for the engineroom messenger. Stretcher Bearer (BTFA) assists in securing fireroom spaces and in effecting fireroom repairs. He is the relief for the burner watch.

2JZ Talker (MM3 or MMFN) correlates and transmits reports.

2JV Talker (MM3 or MMFN) relays information from main control to repair 5.

Messenger (BTFA) assists in securing fireroom spaces and in effecting fireroom repairs. He is the relief for the fireroom messenger.

REPAIR 5 RESPONSIBILITIES

Repair 5 is responsible for prompt and effective action in the event of major casualties in the engineering spaces and, when requested, should be prepared to aid engineering personnel in handling minor casualties. Securing and lighting off details should be designated within repair 5 with each man assigned specific duties.

Repair 5 will be asked to investigate a space whenever communications are lost or other indications show that a casualty has occurred in the space. If the space is found full of steam or severely damaged, it should be secured immediately from topside and adjacent spaces.

In the event that an engineroom must be secured, the corresponding fireroom, if possible, should steam on the auxiliary line to maintain the highest possible degree of operational readiness. Fluid in any form should not be allowed in the line entering or transiting a space in which a major casualty has occurred until the condition of the lines has been investigated and reported intact or properly isolated to main engine control, and permission has been secured to use the lines.

When entering a damaged space, investigators should ascertain the condition of auxiliary and main steam lines as soon as possible and report their findings to main engine control. A more thorough description of all damage to machinery and lines should follow the initial findings. If damage is in the after fireroom, it is of utmost importance that the auxiliary steam lines be immediately inspected and an undamaged line from the forward engineroom to the after engineroom be isolated from any damaged section. This action is necessary so that auxiliary steam can be rapidly restored to the lube oil pumps in the after engineroom.

Communications from a damaged space to main engine control should be established as soon as possible, using the 2JV circuit. The 1 JV circuit can be used in the after engineroom if the 2JV circuit is damaged. If the 1JV circuit is used, immediate steps should be taken to establish an emergency 2JV circuit to this space.

Repair 5 is responsible for rigging emergency communications circuits. Each man should be familiar with the casualty communication circuit X40J, and a team should be designated to rig this circuit when necessary. All men in repair 5 should also be familiar with all remote operating gear for engineering valves.

OPERATING CASUALTIES

The principal doctrine to be impressed on operating personnel in the event of a casualty of any part of the main plant is the necessity of continued operation, if possible. Try to keep the ship underway except when continued operation would damage the main engines. Notify the engineering officer of the watch as soon as possible; he, in turn, notifies the officer of the deck of the casualty and of any effect on the ship's speed or the ability to answer bells. The engineering officer of the watch also notifies the engineer officer.

Before cross-connecting, due to loss of steam pressure in one plant, investigate the cause of the loss of pressure. Remember that cross-connecting to a ruptured line can cause loss of pressure throughout the plant. If loss of steam pressure is due to a ruptured line or battle damage, isolate the damaged section thoroughly before cross-connecting. Ensure that lube oil pressure is maintained to the turbine at all times. In the event the auxiliary steam cannot be cross-connected and lube oil pressure cannot be maintained either by the steam-driven or electric standby pump, the shaft should be stopped.

FIREROOM CASUALTIES

Under all circumstances, the Boiler Technician notifies the engineroom of the fireroom casualties.

Engineroom action to be taken is based on the report given by the Boiler Technician. When a fireroom casualty affects the operation of the engineroom, cooperation and communication between personnel of both the spaces are extremely important.

Some of the fireroom casualties that affect the engineroom, and the procedures for controlling them, are listed in the following paragraphs.

High Water

In the event of the fireroom casualty, HIGH WATER IN BOILER, with split plant operation, the Electrician's Mate should trip the ship's service generator circuit breaker and close the a.c. and d.c. bus-ties, and the Machinist's Mate should close the main engine throttle and trip the ship's service turbogenerator. All steam line drains and all turbine drains should be opened to ensure that all water is drained from the steam lines and turbines before the cross-connection valve is opened. The plant should then be cross-connected to receive steam from another boiler. These procedures should be carried out simultaneously. The fireroom watch should close the feed check valve, secure the burners, stop the blowers, and close the main, the turbogenerator, and the auxiliary boiler steam stop valves. After the boiler is secured, the fireroom watch should run down the water to the steaming level, relight fires, and bring the boiler on the line.

Low Water

The fireroom casualty, LOW WATER IN BOILER, also requires that the affected boiler be secured. It is not necessary to trip the ship's service generator as in the case of high water. However, speed in cross-connecting is important to maintain steam to the turbine.

Failure of Forced Draft Blower

Failure of a forced draft blower can be serious, depending on the existing conditions. If two blowers are in use and the speed of the ship is high, the ship will have to be slowed. If only one blower is in use, its failure will necessitate securing the boiler until another blower can be started. If there is only one boiler furnishing steam to a space, the Machinist's Mate should cross-connect the space and take steam from another boiler.

Loss of Fuel Oil Suction

The loss of fuel oil suction will cause the burners to sputter, fires to die out, and possible sudden racing of the fuel-oil service pump.

The fireroom watch secures all burners, leaving at least one air register on each side (superheated and saturated) open to expel any gases and to supply air for combustion of any oil that may have accumulated on the boiler floors. The forced draft blowers are kept running to purge the furnace (use purge chart applicable to ship's boilers).

The standby pump should be started with suction on the standby service tank. The watch notifies the engineroom of the casualty and that the fires are secured, and, if unable to regain fires before steam pressure drops to the predetermined value, notifies the engineroom that the boiler is being secured by closing the main, turbo, and auxiliary boiler steam stops in the order indicated.

The fireroom watch should notify the engineroom that the boiler is secured and open the cross-connecting valves when so directed by the engineroom. The service pump discharge pressure should be observed. If the pump races and the noise level increases, there is water in the oil, and, if no pressure is indicated, the pump is air bound. If there is water in the oil, the watch should run the oil to the contaminated oil tank through the recirculating line until the service line is free of water. If the pump is airbound, the priming cock should be opened and the system vented.

The BT should close the air registers and slow down the forced draft blower after all oil has been burned from the furnace deck and all combustible gases expelled. After it has been determined that good oil is available, he should carry out the procedure for placing a boiler on the line.

The BT should then investigate and correct the cause of the trouble and sound the tank to determine the quantity of oil in the tank. If the oil is above the suction line, the fuel oil is contaminated or the suction line is clogged. If the fuel oil contains water, he should sound the tanks in use and from which oil was transferred to find the source of the contamination.

ENGINEROOM CASUALTIES

The operational engineroom casualties that might occur include excessive vibration of a shaft, vibration of a turbine, loss of lube oil, and many others.

Excessive Vibration of Shaft

If a shaft develops excessive vibration, the man on watch should obtain permission to slow the engine until the vibration ceases, and speed up the other engine to maintain speed, as the tactical situation requires. If vibration continues at all speeds, he should obtain permission to stop and lock the shaft to investigate the shaft bearings. If the cause is undetermined, he should investigate the propeller, fairwaters (sleeves), and rope guards at the first opportunity.

Vibration of Turbine

If a turbine begins to vibrate, the men on watch should, with permission, slow down the engine and reduce the superheat temperature. A rumbling noise probably indicates the presence of water in the casing, either from boiler priming or inadequate casing drainage.

If the turbine has been standing idle for more than 5 minutes without being spun, it is probable that the rotor has been bowed temporarily. Upon restarting the turbine, vibration may be evident and, if so, a brief slowing of the turbine will usually permit the rotor to straighten.

Loss of Lube Oil

It should be impressed on all personnel concerned that even a momentary loss of flow of lubricating oil can result in localized overheating and probable slight wiping of one or more bearings. Such wiping may result in only a momentary rise in the temperature of the lubricating oil discharge from the bearing(s). Damage can be prevented or minimized by stopping the shaft rotation and quickly restoring the lubricating oil flow. Continued operation with wiped bearings can cause serious derangement to the shaft packing, oil seals, and blading.

Loss of lubricating oil pressure may be caused by failure of the system itself, including the main lubricating oil pumps; failure of steam or electrical power supply to the main lubricating oil pumps; or damage to boilers, steam lines, or electrical equipment.

Failure to component parts of the lube oil system may be caused by the presence of dirt, rags, or other foreign matter resulting from improper cleaning. Failure of the system may be caused by a piping failure, by a failure of the operating pump, or by failure of the standby pump to start. Standby pumps should be maintained ready to start the moment the pressure drops below the prescribed operating range. If automatic starting devices are not available on steam-driven pumps, the pumps should be lined up so that opening the throttle is the only action required to start the pumps. Steam supply lines to standby pumps should be drained continuously. Where electrical pumps are installed, personnel should be thoroughly familiar with alternate sources of power.

The general procedure when low lubricating oil pressure occurs is to immediately stop the affected shaft and simultaneously endeavor to regain lubricating oil pressure.

If steam pressure is available, stop the shaft by using the astern throttle. Engage the jacking gear and apply the brake. If the speed is in excess of one-half full power speed, stop the shaft by means of the astern turbine, slow down the ship to a safe speed, and then lock the shaft. Listen for, and endeavor to locate, the source of any unusual or abnormal sounds. After the affected shaft is secured, the ship's speed may be increased to the limit for locked shaft operation.

If steam pressure is lost in one engineroom during split-plant operation and the tactical situation permits, take way off the ship by backing the other engine. Determine the nature of the casualty causing the loss of steam. If a loss of steam pressure in the engineroom will not cause a loss of steam to the other plant, open the auxiliary and the main steam cross-connections immediately. If the damage caused a loss of steam to the other plant, isolate the damage and then open the auxiliary and the main steam cross-connections as soon as possible. Stop and lock the affected shaft as soon as steam is available.

ELECTRIC PLANT CASUALTIES

Knowing the maximum operating limits of the electric plant is of prime importance during casualty operation. You must know the maximum allowable bearing temperatures, generator winding temperatures, maximum generator loads, etc.

Supplying vital power during casualty operation may require that generators be operated under overload conditions. Assuming that the prime mover can handle the overload, the temperature of the generator windings is the determining factor during sustained overloads. A portable blower may be used on open type machines to keep the winding temperature within safe limits.

Operational electric plant casualties that might occur include loss of generator, electrical fires, loss of lube oil, and overloaded generator.

Additional information concerning casualties to the DDG-2 class destroyer and the DLG-23 is contained in *Electrician's Mate 3 & 2*, NAVEDTRA 10546-D. This information includes the operation of emergency diesel generators and their operation under emergency conditions.

Electrical Fires

The proper procedure in the event of an electrical fire is for the assigned Electrician's Mate to deenergize the power supply to the affected controller, power panel, or switchboard and make certain that all power is off (normal, alternate, and emergency.) Then he reports the fire to the engineering officer of the watch and the officer of the deck, uses a CO_2 fire extinguisher on the fire, and secures all ventilation. He should not stand directly in front of the panel that is on fire. He should keep low and to one side and set a reflash watch until the danger of a reflash has passed. The electrician should open the panel with rubber gloves, using a rubber mat or boots, as additional insulation, to determine and repair the source of trouble.

If an electrical fire should occur in a switchboard with a generator on the line, the circuit breaker should be tripped (refer to fig. 9-6) and the Machinist's Mate should trip the overspeed trip on the generator and notify the control engineroom, which in turn notifies the officer of the deck and the engineering officer.

The Electrician's Mate should secure the voltage regulator, trip the bus-tie circuit breaker and open the feedback circuit breaker. If the fire is in the forward switchboard he should notify the after switchboard watch to open the after bus-tie circuit breaker and then he should use a CO_2 fire extinguisher on the fire. The damaged section of the switchboard should not be reenergized until repairs have been made.

If an electrical fire occurs in a generator, the generator should be secured immediately. If the fire occurs while operating split plant, the Electrician's Mate should trip the generator circuit breaker for the affected generator, close the bus-tie, and use a CO_2 fire extinguisher on the fire. If a generator fire should occur during operation with a single generator, the

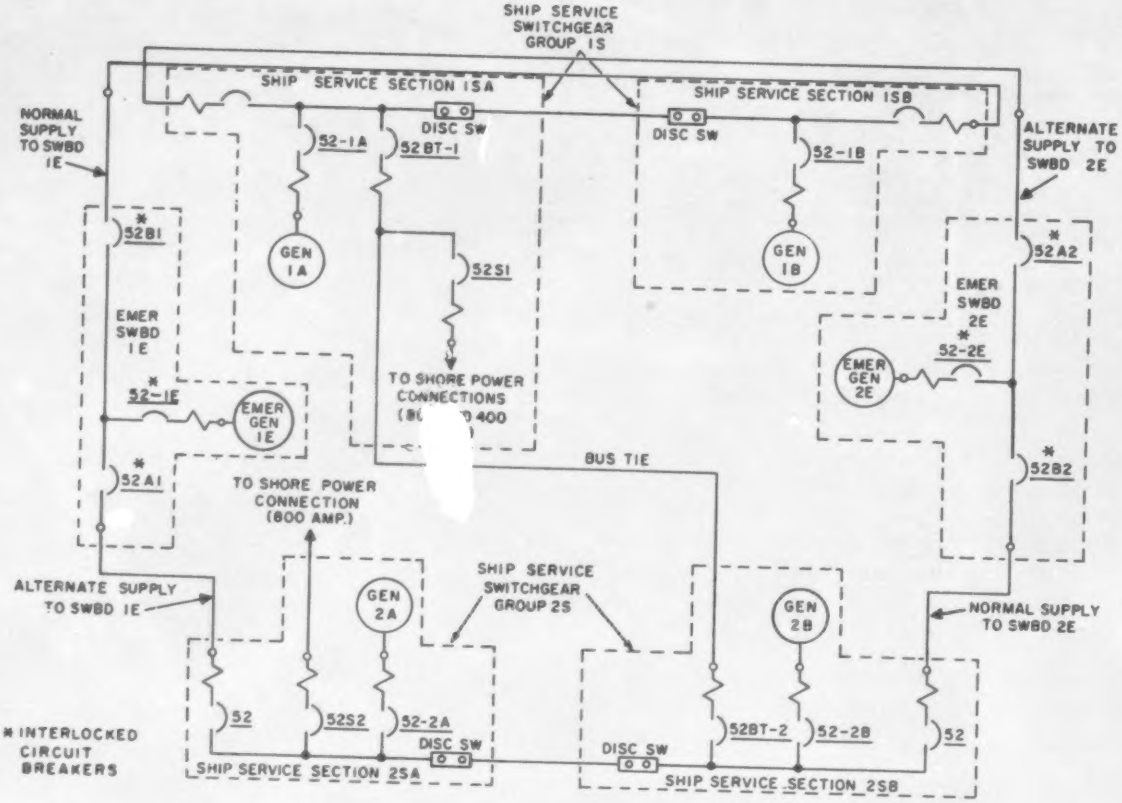

SHIP SERVICE
SWITCHGEAR
GROUP 1S
SHIP SERVICE SECTION 1SA
SHIP SERVICE SECTION 1SB
DISC SW
DISC SW
52-1A
52BT-1
52-1B
NORMAL
SUPPLY
TO SWBD
1E
ALTERNATE
SUPPLY TO
SWBD 2E
*
52B1
GEN
1A
52S1
GEN
1B
*
52A2
EMER
SWBD
2E
EMER
SWBD
1E
*
52-2E
EMER
GEN
2E
*
52-1E
EMER
GEN
1E
TO SHORE POWER
CONNECTIONS
(80 400
*
52A1
BUS TIE
*
52B2
TO SHORE POWER
CONNECTION
(800 AMP.)
ALTERNATE SUPPLY
TO SWBD 1E
SHIP SERVICE
SWITCHGEAR
GROUP 2S
GEN
2A
GEN
2B
NORMAL SUPPLY
TO SWBD 2E
52
52S2
52-2A
DISC SW
52BT-2
52-2B
52
DISC SW
* INTERLOCKED
CIRCUIT
BREAKERS
SHIP SERVICE SECTION 2SA
SHIP SERVICE SECTION 2SB

Figure 9-6.—Power distribution (60 hertz) system on a DLG.

77.252

switchboard should be stripped of all nonvital circuits and the vital circuits supplied from the emergency diesel generator.

Loss of Lube Oil

Upon failure of generator lube oil pressure, the electrical load should be removed from the affected generator, and the generator should be stopped immediately. The normal procedure is to trip the generator circuit breaker, close the bus-tie, and close the generator turbine throttle valve. The hand-operated lube oil pump should be used to maintain lube oil pressure to the bearings until the turbine is completely stopped. After the turbine has stopped, investigate and correct the casualty.

Overloaded Generator

Overload on a generator, is reduced by removing nonvital loads. Power should not be interrupted to vital machinery and circuits unless absolutely necessary. Vital machinery and circuits include the steering gear, IC switchboard, fire pumps, drainage pumps, vital auxiliaries in the boiler and enginerooms, gun mounts, and navigational lights.

DIESEL ELECTRIC D.C. DRIVE (FLEET TUG) CASUALTIES

Operational casualties that may occur to this type of drive may include casualties to any one of the four main propulsion generators or exciters, the main propulsion motor, and the control equipment and associated circuits.

PROPULSION GENERATOR CASUALTY

A casualty to one of the main propulsion generators or associated exciter requires cutting the affected generator out of the series propulsion loop.

It is not necessary to turn the speed controller to the STOP position when cutting a generator into or out of the propulsion circuit. Normally, the controller should be brought to a position not higher than the 11th (engine operating at 350 rpm). When required, a generator may be cut out of the circuit while the engine speed is in excess of 350 rpm as the generator setup switches are designed for such service. Wait several seconds between the opening of the generator's control switch and its setup switch. This reduces arcing at the setup switch contacts, and prevents flashover of the generator commutator.

CONTROL CONSOLE CASUALTY

A casualty to the pilothouse control console or associated circuitry requires a shift in control of the engines to the engineroom station. To shift control to the engineroom, place the controllers at both control stations on the STOP position, turn the excitation control switch to OFF, turn the engineroom-pilothouse control transfer switch to the ENGINEROOM position (the control transfer switch and the excitation control switch are interlocked so that the excitation control switch has to be in the OFF position before the control transfer switch can be operated), and then turn the excitation control switch to ON.

BATTLE CASUALTIES

Shell or torpedo hits in engineering spaces usually result in multiple casualties to machinery and systems. The corrective action for any particular casualty depends on the location and extent of damage. While battle casualties differ in many respects, the following procedures can be applied to most casualties of this type.

Secure the space or isolate damaged sections, as practical, and cross-connect systems or plants, when possible.

Carry out applicable casualty control procedures in the event of damage to machinery or piping systems, such as: stop and lock the shaft in the event of serious damage to the turbine, reduction gear, or the main shaft or loss of lubricating oil pressure to the main engines and use soft patches, blank flanges, wooden plugs, or other suitable means to repair lube oil lines, fresh water lines, salt-water cooling mains, auxiliary exhaust lines, and other low pressure lines.

If a ruptured steam line prevents entry of repair party personnel into a space, secure the space by using remote controls.

Take all precautions to prevent flooding of the space. Put all available pumps on the bilges of the damaged space; plug all holes, and, if possible prevent flooding of other spaces.

Extinguish fires, investigate damage, and make repairs to return machinery or the space back to service, if practicable, as soon as possible.

Keep communication lines open and keep main engine control advised of the existing conditions.

DAMAGED CABLE AND EQUIPMENT

In any casualty involving damage to electrical cable and equipment, electrical circuits may be a hazard if they remain energized. The circumstances surrounding each case of damage will dictate the action to be taken. In cases of serious damage it is usually necessary to remove electrical power from all cables in the damaged area to prevent the ignition of combustible liquids and gases. Continued operations, however, may require the reestablishment of power to undamaged circuits, including those that extend through the damaged area.

Splices may be made or temporary jumpers may be run in some cases to reestablish power to the required circuits. Lighting circuits are not to be disregarded in this connection because damage control activities can be seriously handicapped or rendered impossible by inadequate lighting at the scene of damage.

Damaged electrical equipment should be isolated from all available sources of power. In case of a damaged switchboard, all circuits feeding to the switchboard from remote sources should be deenergized and tagged at the source.

CASUALTY POWER SYSTEM

The casualty power system of a DDG-2 destroyer is described in *Electrician's Mate 3 & 2*, NAVEDTRA 10546-D. The system is limited to bare minimal electrical facilities required to keep the ship afloat in the event of damage and to get it out of a danger area. Important basic features of the casualty power system include the preservation of the watertight integrity of the ship, simplicity of installation and operation, flexibility of application, interchangeability of parts and equipment, minimum weight and space requirements, and the ability to accomplish the desired functions.

The casualty power system is a temporary means of providing power and is not a means of making temporary repairs. To retain effectiveness, the system is purposely limited in its scope. The more equipment that is added and the more the system is expanded, the greater will be the possibility of error in making connections as well as the possibility of faults at relatively unimportant equipment causing loss of power at vital equipment. It is also probable that the casualty power system, if expanded, would be burdened with miscellaneous loads at a time when its use would be essential for vital loads.

The electrical casualty power system in a typical destroyer is illustrated in the schematic diagram in figure 9-7. The system contains no permanently installed cables, except for the vertical risers and bulkhead terminals. The risers are installed to carry circuits through decks without impairing the watertight integrity of the ship. A riser consists of a TSGA-60 cable extending from one deck to another with a riser terminal connected to each end for attachment of portable cables.

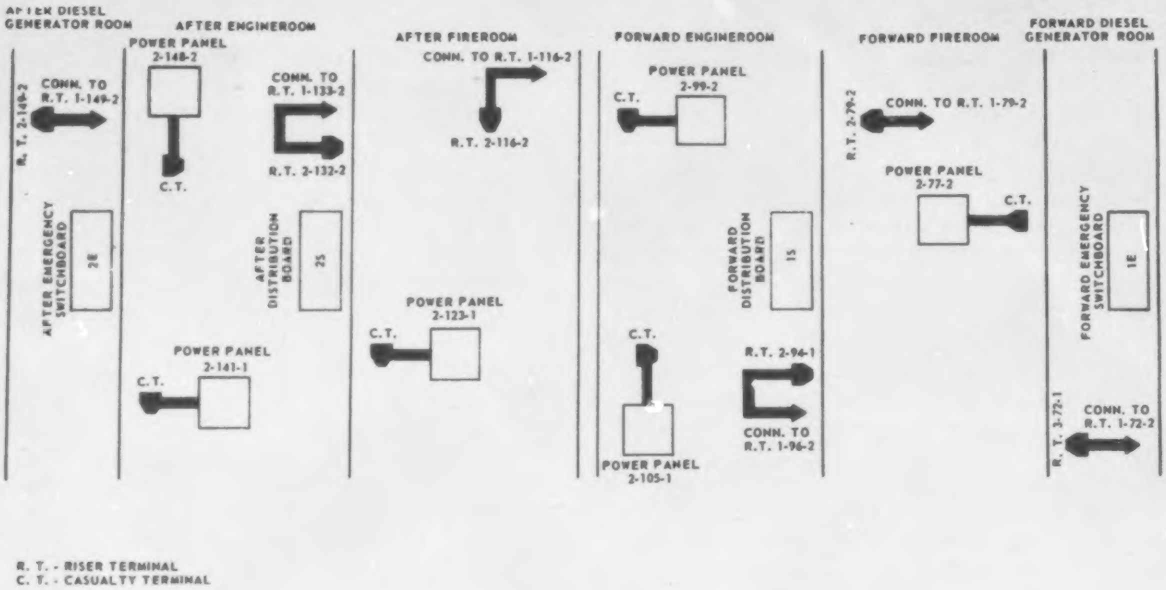
Portable THOF-42 cables in suitable lengths form all the circuits required to supply power to equipment designated to receive casualty power. While the normal current carrying capacity of THOF-42 cables is 93 amperes, its casualty rating is 200 amperes. Under normal conditions this cable will carry 200 amperes for 4 hours without damage to the cable.

The bulkhead terminals carry circuits through bulkheads without impairing the watertight integrity of the ship.

The power panels supplying equipment designated for casualty power service are equipped with terminals so that casualty power can be fed into the panels. These panels can also be used as a source of power for the casualty power system in the event that power is still available from the permanent feeders to the panels. However, the decision to take power from the panel instead of the switchboard should be based on knowledge that equipment on that panel will not be required for the safety of the ship. Operating the equipment that is normally supplied by the panel plus the equipment to be supplied with casualty power may cause an overload on the circuit breaker supplying the panel. Portable switches are located in several strategic positions throughout the ship for use with the casualty power system.

In general, the casualty power system provides a horizontal run of portable cable along the main deck with risers for the power supply and for loads extending to and from this level. Rigging and unrigging casualty power cables are described in *Electrician's Mate 3 & 2*, NAVEDTRA 10546-D.

The ship's service switchboards, 1S and 2S, and the emergency switchboards, 1E and 2E, are provided with casualty power terminals, installed on the back of the switchboard. Each casualty power terminal is connected to the buses through a standard 250-ampere AQB circuit breaker. The circuit breakers have an


AFTER DIESEL GENERATOR ROOM
AFTER ENGINEROOM
AFTER FIREROOM
FORWARD ENGINEROOM
FORWARD FIREROOM
FORWARD DIESEL GENERATOR ROOM
R. T. 2-149-2
CONN. TO R.T. 1-149-2
AFTER EMERGENCY SWITCHBOARD
2E
POWER PANEL 2-148-2
C.T.
CONN. TO R.T. 1-133-2
R.T. 2-132-2
AFTER DISTRIBUTION BOARD
2S
POWER PANEL 2-141-1
C.T.
CONN. TO R.T. 1-116-2
R.T. 2-116-2
POWER PANEL 2-123-1
C.T.
POWER PANEL 2-99-2
C.T.
FORWARD DISTRIBUTION BOARD
1S
C.T.
POWER PANEL 2-105-1
R.T. 2-94-1
CONN. TO R.T. 1-96-2
R.T. 2-79-2
CONN. TO R.T. 1-79-2
POWER PANEL 2-77-2
C.T.
FORWARD EMERGENCY SWITCHBOARD
1E
R. T. 3-72-1
CONN. TO R.T. 1-72-2
R. T. - RISER TERMINAL
C. T. - CASUALTY TERMINAL

103.1

Figure 9-7.—Electrical casualty power system.

instantaneous (magnetic) trip element setting to prevent tripping of the generator breaker or fusing of the casualty power cable under short-circuit conditions. Connections to the buses are between the generator circuit breaker and disconnect switch.

CASUALTY CONTROL TRAINING

Knowledge is the keystone of casualty control. Maximum knowledge of the operating details of the engineering installation should be imparted to the greatest possible extent to all engineering personnel. Instruction in casualty procedures should be based on thorough knowledge of the proper and normal operating procedures of the plant. Complete familiarity with normal operation should be gained by all personnel concerned before any attempt is made to carry out simulated casualties.

Casualty control training should be a continuous step-by-step procedure with constant refresher drills. These drills comprise ON-STATION training with frequent instruction and inspection of watch sections by engineering officers and leading petty officers to ensure that the men are indoctrinated in the proper procedures and are familiar with the installations in their machinery space. Instructions pertaining to the machinery setup for various engineering conditions of readiness should be well promulgated and inspections should be made to ensure that these instructions are carried out.

Realistic simulation of casualties should be preceded by adequate preparation. The amount of advance preparation necessary is not always readily apparent and care should be exercised to visualize the full consequences of error, which may be made in the handling of simulated casualties intended to be of a relatively minor nature. Hence, the simulation of major casualties and battle damage should be preceded by an extremely complete analysis and by careful instruction to all participants.

Any new crew should be given an adequate opportunity to become familiar with the ship's systems and equipment prior to simulating any casualty that may have other than purely local effects. In the preliminary phases a so-called DRY RUN is a useful method for imparting early knowledge of casualty control procedures without endangering the ship's equipment.

Under the dry-run procedure, a casualty is announced and all individuals are required to report as though action were taken, except to indicate that action was only simulated. Definite corrective actions can be made and, with careful supervision, the timing of individual actions can be made very realistic. Such dry runs should always be carried out before any realistic attempt is carried out to simulate any involved casualty, regardless of the state of training.

Individual casualty procedures should be the basis of casualty control training with emphasis on operating casualties in the early stages. Conducting battle problems before a crew is proficient in handling operating casualties only results in confusion and disrupts the efforts to organize and coordinate the teams. A battle problem is a sequence of individual casualties which requires individual casualty control procedures by the teams as well as intraplant coordination between teams. With well organized training in individual casualties and with good communications, a crew can proficiently handle any battle problem.

CONDUCTING AND SUPERVISING ELECTRICAL CASUALTY DRILLS

As an EM1 or Chief Electrician's Mate, you will be required to conduct and supervise electrical casualty drills. This will include conducting such drills as fires in generators, switchboards, and other electrical equipment, emergency securing of generators, use of emergency generators, stripping switchboards of nonvital circuits, supplying casualty power to vital machinery, and others.

In addition to conducting frequent dry runs, you should ensure that all Electrician's Mates get some experience in actually performing the casualty operations. The men stationed on the switchboard during general quarters will get electric plant casualty operating experience during general quarters drills. You should ensure that the other switchboard watchstanders get this experience. Always obtain permission from appropriate authority, however, before conducting any casualty drills that may affect the status of the engineering plant.

CHAPTER 10

MAINTENANCE ADMINISTRATION

Maintenance of ships can be divided into two broad categories: preventive maintenance and corrective maintenance. Preventive maintenance consists of routine shipboard procedures that increase the effective life of equipment or forewarn of impending troubles. Corrective maintenance consists of procedures that analyze and correct material defects and troubles. The main objective of shipboard preventive maintenance is to prevent breakdown, deterioration, and malfunction of equipment. If, however, this objective is not reached, the alternative is corrective maintenance–repairing or replacing the failed equipment.

In the past, shipboard maintenance programs varied from one command to another, resulting in various degrees of operational readiness. The system now in use is the Navy Maintenance and Material Management (3-M) System. It is designed to upgrade the operational readiness of ships. The system is introduced in *Military Requirements for Petty Officer 3 & 2*, NAVEDTRA 10056-C and *Military Requirements for Petty Officer 1 & C*, NAVEDTRA 10057-C. We recommend that you review that material before you begin this chapter.

The 3-M System should not be considered a "cure all" for your equipment and maintenance problems. The procedures of the system are intended to obtain the most accurate and complete information possible by collecting reports directly from the ship's maintenance personnel. The reports are analyzed, and the results are sent to maintenance activities, logistics activities, and design activities in the form of improved procedures and/or recommendations for design changes. The system also produces a large reservoir of knowledge about equipment disorders which, when fed back to the appropriate sources for analysis, should result in the distribution of information regarding corrective steps to prevent recurrences. Obviously, the correctness of the results depends on the accuracy of the basic reports.

The 3-M System, like any other system or program, is only as good as the personnel who make it work. Your role in the system as a PO1 or CPO will include the training of lower rated personnel in its use, as well as the scheduling and supervision of maintenance. In addition to the information found in *Military Requirements for Petty Officer 3 & 2* and *Military Requirements for Petty Officer 1 & C*, details on the system and changes related to it are available in the *Maintenance and Material Management (3-M) Manual* (revised). Other sources of information include OPNAV Instruction 4700.16 (revised), the *NAVSEA Journal*, and directives issued by type commanders.

SCHEDULING OF PLANNED MAINTENANCE

The planning and scheduling of planned maintenance is accomplished through the Planned Maintenance Subsystem (PMS). In addition, the PMS defines the MINIMUM maintenance required, controls its performance, describes the methods, materials, and tools to be used, and aids in the detection and prevention of impending casualties. These factors should prove to be a definite asset to the leading petty officer in forecasting future material requirements and in the proper utilization of available manpower.

It should be noted that the PMS DOES NOT cover certain operating checks and inspections that are required as a normal part of the regular watchstanding routine. For example, you will not find such things as hourly voltage and current checks or routine gyro checks listed as maintenance requirements under the PMS. Even though these routine operating checks are not listed as PMS requirements, you must, of course, still perform them in accordance with all applicable watchstander's instructions.

The Planned Maintenance Subsystem is based on the proper utilization of PMS Manuals, Maintenance Requirement Cards (MRC's), and schedules for the accomplishment of planned maintenance actions.

The PMS uses the Cycle Schedule, the Quarterly Schedule, and the Weekly Schedule to simplify the scheduling of planned maintenance. All required planned maintenance actions are programmed throughout the overhaul cycle of a ship. In addition, the system is flexible enough to readily accommodate any changes in a ship's employment schedule. The schedules are discussed in detail in *Military Requirements for Petty Officer 1 & C*, NAVEDTRA 10057-C.

RECORDING OF MAINTENANCE ACTIONS

The Maintenance Data Collection Subsystem (MDCS) provides a means of recording information concerning both planned and corrective maintenance actions. Maintenance performed is recorded by code in sufficient detail to collect a great variety of information concerning maintenance actions and the performance of the equipment involved. The codes used in recording and reporting maintenance actions permit machine processing with automatic data processing equipment. The system also provides data concerning the initial discovery of a malfunction, how the equipment malfunctioned, how many hours the equipment was in operation, which equipment was involved, what repair parts and materials were used, what delays were incurred, the reason for delay, and the technical specialty or work center which performed the maintenance. Each maintenance action is reported in this manner, except for the routine preservation actions such as chipping, painting, and cleaning.

The shipboard installation of the Maintenance Data Collection Subsystem includes a central, functional data collection center. The primary function of the shipboard data collection center is to screen all documents for completeness and accuracy before they are forwarded to the data processing center. During the screening process, the data collection center adds a four-digit maintenance control number to each document unless the person doing the task has already received and entered a maintenance control number to obtain parts or materials from the supply department.

Initially, the effectiveness of the MDCS depends on the accuracy of the report by the individual performing the maintenance action. Leading petty officers are responsible for ensuring that all forms used in connection with the MDCS are complete and accurate. Leading petty officers should also ensure that a form is submitted for each applicable action, and that no action is reported more than once.

EQUIPMENT IDENTIFICATION CODE MASTER INDEX (EIC MANUAL)

All personnel having any responsibility for maintenance actions must know how to use the EIC Manual. The EIC Manual contains many codes used in reporting maintenance actions. Each major system is coded and broken down to a level which identifies it. This, in turn, will help you maintain your equipment. The following example shows you how to obtain an EIC number. You want the slip rings on the rotor of the steam turbine driven 60-Hz ship's service generator trued and cleaned. Look in the EIC Manual Index table of contents. Notice that the electric power generation systems code is 3000000. Now turn to the page indicated to find the further breakdown. You will notice that the generator set, 60-Hz, steam turbine driven is 310C000. The number 3 identifies the component as electrical power generation systems. The 10C identifies the component as ship's service, 60-Hz, steam driven. With this code you have identified the component of the unit where a problem is located. This information can aid logistics personnel in supplying spare parts and engineers in solving design problems.

MDCS DOCUMENTATION

Information for the MDCS is documented on standard forms such as the Maintenance Data Form and the Feedback Report. Detailed descriptions of the forms are listed in Section I of the EIC Manual, the *Maintenance and Material Management (3-M) Manual* (revised), and the *Military Requirements for Petty Officer 3 & 2*, NAVEDTRA 10056-C.

MAN-HOUR ACCOUNTING SYSTEM

The Man-hour Accounting System, sometimes referred to as Exception Time Accounting (ETA), is used by the repair department of a repair activity in conjunction with the MDCS. It is basically a management tool and accounts for deviations from a normal 7-hour working day.

ETA includes the use of codes, the preparation of a Master Roster Listing, and the preparation and submission of Daily Exception Cards (OPNAV Form 4700-2E). Detailed procedures for using the card are discussed in the *Maintenance and Material Management (3-M) Manual* (revised) and the *Military Requirements for Petty Officer 1 & C*.

REPAIRS AND ALTERATIONS

As a senior petty officer, your concern with repairs and alterations depends to a great extent on where you stand in the chain of command. In the following section we will consider several areas of a repair period and cover various definitions.

A REPAIR is defined in *Navy Regulations* as "work necessary to restore a ship or article to serviceable condition without change in design, materials, number, location, or relationship of the component parts" and an ALTERATION is defined as "any change in the hull, machinery, equipment, or fittings which involves a change in design, materials, number, location, or relationship of the component parts of an assembly regardless of whether it is undertaken separately from, or incidental to, or in conjunction with, repairs."

A NAVALT is an alteration that affects the military characteristics of a naval vessel. NAVALTS are identified by the word NAVALT, and a number, if any, assigned to the project in the Ship Improvement Guide. (The issuance of a Ship Improvement Guide project card, or a class Improvement Plan which describes the alteration, indicates that the alteration has been approved or is under active consideration.) The document that describes the alteration in detail and lists the specific vessels to which it is applicable is also known as a NAVALT.

A SHIPALT is an alteration under the technical cognizance of NAVSEA, regardless of whether it affects the military characteristics of a vessel. Thus, some alterations may be both NAVALTS and SHIPALTS whereas others may be only SHIPALTS. The document that describes an alteration and lists the specific vessels to which it is applicable is also known as a SHIPALT.

Each SHIPALT is identified by a composite number consisting of two serial numbers and a letter. Serial numbers are assigned chronologically in the order in which alterations are approved. The first serial number is the TYPE SERIAL NUMBER (the number of the alteration within a type). The letter indicates the expenditure account chargeable. And the second serial number is the SHIP SERIAL NUMBER (the number of the alteration for a specific ship within the type).

For example, consider SHIPALT CVA 150A70-FORRESTAL. CV is the ship type designation (in this case an attack carrier); 150 indicates that this is the 150th alteration approved for CV's; "A" designates the account to which the charges will be made.

TYPE AVAILABILITIES

AVAILABILITY is defined in *Navy Regulations* as "the period of time assigned a ship by competent authority for the uninterrupted accomplishment of work which requires services of a repair activity ashore or afloat."

To say that a ship has been granted an availability means simply that she is available for maintenance work because a competent authority, usually the fleet commander, has suspended her operational schedule for a specific period to permit accomplishment of work at a repair activity. A repair activity may request that availability be extended so that work can be completed, or the activity may recommend a completion date to the proper authority.

There are four availabilities for shipyard or other shore-based repair activities. These are regular overhauls, restricted availability, voyage repairs, and technical availability.

A regular overhaul is normally scheduled in advance and in accordance with an established cycle to accomplish general repairs and alterations. The restricted availability is assigned only for specific items of work, normally with the ship present. During a restricted availability the ship is rendered incapable of fully performing its assigned mission. Voyage repairs are emergency work necessary to enable the ship to continue on its mission. These repairs must be accomplished without a change in the ship's operating schedule. A technical availability is assigned for specific items of work, normally with the ship not present. As opposed to a restricted availability, a technical availability leaves the ship fully capable of performing its assigned mission.

For tenders or repair ships, four other availabilities are assigned. These are regular tender availability, emergency tender availability, parent tender/automatic availability, and concurrent availability.

A regular tender availability is normally scheduled in advance for general repairs and authorized alterations which are beyond the capacity of the ship's force alongside. An emergency tender availability is assigned to render repairs to specific casualties. These repairs take first priority over other tender work. A parent tender/automatic availability is used to accomplish items of work usually on a ship-to-shop basis. The repairs are normally of a nonoperational nature and are done on an unscheduled basis. Concurrent availability is scheduled to coincide with the regular shipyard overhaul or restricted availability for the accomplishment of ship-to-shop work by a tender or repair ship.

Support availability is for specific items of work for units or commands other than a ship (such as an afloat staff or shore-based activity). Any availability for the accomplishment of work on a naval reserve training (NRT) ship falls under an NRT ship availability.

To illustrate, let us use a motion picture projector to learn when routine repair work can be accomplished by a repair facility.

Motion picture projectors are sent to a motion picture equipment repair facility, tender, or repair ship every 1000 hours of operating time; when maintenance is beyond the technical skills of personnel aboard the command; or if the necessary tools and gages are not available aboard the command.

Support availability and NRT ship availability are two availabilities which can be assigned to either ship or shore repair facilities.

The projector will normally be sent to a repair facility, tender, or repair ship during any of the above availabilities except during restricted availability, voyage repairs, technical availability, or emergency tender availability. In practice the projector could be sent even during these availabilities as long as it does not interfere with the primary repair mission or the repair activities normal work load.

REPAIR PROCEDURE

As a first class or chief petty officer, you will sometimes be required to supervise or otherwise participate in general shipboard repair or other repairs to EM areas. This section on repair procedures will help you better understand the normal, or required, repair procedures.

REPAIR SHIPS AND TENDERS

Originally, the repair ship (AR) was intended primarily for repairing battleships and cruisers.

During World War II several types of repair ships were developed for specialized types of work; for example, the landing craft repair ship (ARL). Repair ships perform repair and maintenance functions that are beyond the capabilities of other ships' facilities or personnel.

Tenders perform repair work, supply repair parts, and render other services to the ships they serve. At present there are two types of tenders in service; the destroyer tender (AD) and the submarine tender (AS).

UPKEEP PERIOD

Generally, the type commander will authorize a 2-week upkeep period during which a tender or repair ship will be available to assist in repairs. To ensure a good upkeep, you should plan in advance (with your division officer) the maintenance you desire to accomplish. As a Group Leader, you should also look into such factors as personnel leave and dental care which may affect your scheduling. A good upkeep requires good planning.

Arrival Conference

On the first day, if not before, of an upkeep period, an arrival conference will be held aboard the repair facility. Your commanding officer and your engineer officer will discuss your needs with the facility personnel. This discussion will include scheduling, services, messing, etc. Your work requests should be made out in such a manner that your jobs will be considered favorably.

Upon completion of the arrival conference, the engineer officer will promulgate a schedule, and you should modify your planning to conform with it.

It is important that you bring ship-to-shop items such as motors, coils, and meters to the tender as scheduled. A personal visit to the electrical and IC repair shops is often quite beneficial. Many details can be discussed over a cup of coffee. You should also follow up your jobs to ensure receipt of proper maintenance.

It is good practice to tag all equipment before it goes to the facility and, as an additional precaution, keep a ready reference of serial numbers. Technical manuals and blueprints should be available to the repair facility. Nonetheless, require a checkout from a competent repair facility representative on all documents. If you show the facility a good, efficient electrical shop, the facility will be more inclined to give you their best work.

Completed jobs should be operationally checked before you ask the assigned officer to sign the job off as completed.

NAVAL SHIPYARDS

Periodically your ship will undergo extensive repairs in a naval shipyard. The condition of your equipment when you leave the shipyard will depend on the yard assigned and your initiative.

The planning department of the yard screens and assigns all work requests to the production department which is responsible for the work being done.

Shops

As an Electrician's Mate, you will have occasion to deal with many shops in the naval shipyard. Of primary concern will be Central Toolroom (Shop 06), Public Works (Shop 07), Electric Shop (Shop 51), and Riggers (Shop 72).

Personnel

The technicians and repairmen of a naval shipyard have ratings just as you have. These men have advanced experience and their rating is a source of pride. The current ratings, in descending order of seniority, are Group Superintendent, Superintendent II, Superintendent I, General Foreman II, General Foreman I, Foreman (Leadingman), and Leader (Head). Be sure you know to whom you are talking when discussing job progress.

OVERHAUL

When your ship is scheduled for an overhaul, the planning department of the yard will go over your work requests months in advance of your arrival. Again, the request should be worked out by you and your division officer to the extent required by the planning department personnel.

A naval officer familiar with the shipyard will be designated Ship Superintendent. He will be assigned by the yard to ensure the adequacy of facilities and the expedition of work. Generally, this officer is aboard from your arrival at the yard until your departure and should, through the proper chain of command, be informed of any delays, bottlenecks, personnel problems, and misunderstandings, which might tend to slow or stop the progress of a good yard overhaul. A Ship Progressman (a civilian from the production department of the yard) will also be assigned to work in conjunction with the ship's superintendent to expedite your overhaul.

Progress of Work

During an overhaul the ship is generally required to submit a weekly report of progress to the type commander. To assist in the computation of this report, a "Shipyard Overhaul Work Progress Chart" (fig. 10-1) is used. The inspector (a senior petty officer) whose name appears on this chart is responsible for keeping it up-to-date. If you are assigned this duty, carry it out to the best of your ability. You are the one who indicates the progress. Therefore, you are personally responsible for its accuracy.

Drydocking

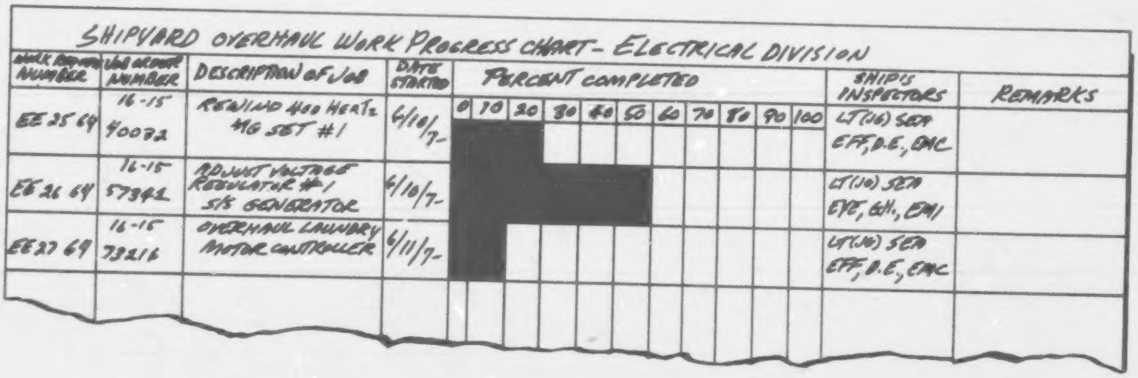
During each overhaul, if facilities are available, the ship will enter drydock for necessary hull work. As a senior petty officer, you should exercise added vigilance during this period because your ship when drydocked, is quite vulnerable to severe damage.

All procedures regarding equipment, fueling, smoking, etc. should be followed to the letter. Ensure that your men are briefed and that they comply to the letter of all drydock regulations.

Post Repair Trials

The dock trial is your opportunity to check out a large part of the overhauled equipment prior to an underway trial. Ensure that your men are stationed at all indicators and that each mode of operation is "checked out." A complete check of all systems is required.

The post repair trial is the final test. Accept nothing but optimum performance from your equipment. Check every item and every mode. This is the checkout that counts. Every



SHIPYARD OVERHAUL WORK PROGRESS CHART - ELECTRICAL DIVISION

WORK REQUEST NUMBER	JOB ORDER NUMBER	DESCRIPTION OF JOB	DATE STARTED	PERCENT COMPLETED											SHIP'S INSPECTORS	REMARKS
				0	10	20	30	40	50	60	70	80	90	100		
EE 25 69	16-15 40072	REWIND 400 HERTZ MG SET #1	6/10/7-	■	■	■									LT(JG) SEA EFF, D.E., EMC	
EE 26 69	16-15 57342	ADJUST VOLTAGE REGULATOR #1 S/S GENERATOR	6/10/7-	■	■	■	■	■	■						LT(JG) SEA EYE, GH., EM1	
EE 27 69	16-15 73216	OVERHAUL LAUNDRY MOTOR CONTROLLER	6/11/7-	■	■										LT(JG) SEA EFF, D.E., EMC	

Figure 10-1.—Representative shipyard overhaul work progress chart.

18.3

discrepancy, no matter how small, should be reported to the electrical officer.

A readiness-for-sea period of approximately 1 week follows during which all "loose ends" should be tied up. A good overhaul starts when your ship enters the yard and ends with the readiness-for-sea trials. It all depends on you and your interest in the job at hand.

INSPECTIONS

To maintain the high standards of readiness, efficiency, and morale on board naval vessels, frequent and varied inspections are required. As a senior electrician, you may be an inspector or you may be inspected. The final section of this chapter will deal with the types of inspections generally encountered.

ADMINISTRATIVE INSPECTIONS

Administrative inspections cover the general administration of the ship as a whole and the administration of each department. This discussion will apply mainly to the engineering department.

The purpose of an administrative inspection is twofold. One, to learn whether the engineering department is being administered in an intelligent, sound, and efficient manner. And two, to determine whether the organizational and administrative methods and procedures are directed toward the objective of every naval ship, namely, the readiness to carry out her intended mission.

GENERAL INSPECTION OF THE SHIP

Items in this section refer to the ship as a whole. Since you have a responsibility for junior men, they too should be borne in mind. Their appearance and that of their living spaces are of paramount importance.

Inspection of the Engineering Department

A departmental checkoff is accomplished for all records and reports which are maintained. To prevent delay, you should ensure that these reports are accessible. There is no reason to "beat around the bush." Answer questions and display your records in such a fashion as to expedite the inspection. Grades are assigned as Outstanding, Excellent, Good, Satisfactory, or Unsatisfactory. Hard work and proper preparation yields the former; the latter is a result of poor work and pool planning. A critique follows the inspection during which deficiencies are covered and the inspection party gives explanations for grades given.

OPERATIONAL READINESS INSPECTION

The aim of this inspection is to test for combat readiness. A realistic battle problem is set up during which the ship's crew goes through evolutions as near to battle conditions as possible. Various problems are imposed such as loss of steering, partial loss of distribution, etc. This is where the training you and your men had in casualty and damage control has its proving ground. This inspection is based not only on your knowledge and abilities relating to the ship's electrical systems, but also on coordination and teamwork.

MATERIAL INSPECTION

Your equipment and your diligence in maintaining it are the paramount items considered in a material inspection. The Board of Inspection and Survey, when directed by the CNO (usually every 3 years), inspects the ship for material condition prior to regular overhaul. Their purpose is to ascertain the suitability of your ship for naval service and which repairs, alterations, and design changes should be made. New vessels must be inspected by a Board prior to final acceptance.

Forces Afloat Inspection Teams will, in all likelihood, be composed of men from another ship of your class. This inspection is conducted using standard forms and is preceded by condition sheets upon which you list your equipment status. Various pieces of equipment will require securing, opening, and partial disassembly.

A critique will follow and a final report is sent to the type commander.

OPERATIONAL TRIALS

Various trials are run periodically on naval vessels. These include builders, preliminary acceptance, final acceptance, post repair, laying up or preoverhaul, recommissioning, full power, and economy.

Generally, the full power and economy trials scheduled by the type commander are of interest to all engineers, and the primary task for the electrician's mate is recording the switchboard instrument readings at prescribed intervals.

The other trials mentioned will vary in workload depending on the amount of repairs which have preceded them or the equipment being tested.

CHAPTER 11

VISUAL LANDING AIDS (VLA)

Visual landing aids (VLA) are a complement to the Light Airborne Multiple Purpose System (LAMPS). LAMPS is found aboard nonaviation ships and consists of ship and air integration in which a helicopter is used as an extension of the shipboard surveillance and attack systems. The original integration concept of LAMPS was limited to daytime operations and fair-weather conditions. Because of increasing demands for all-weather and night operations, a lighting system (VLA) was designed to aid the LAMPS concept. VLA consists of specially designed lights to provide the helicopter pilot with:

1. An initial visual contact with the ship

2. A safe glide path to the landing area

3. Precise information (visual cues) relative to the ship's deck position and any obstructions that may be present during launch and recovery operations

4. Visual indications for helicopter in-flight refueling (HIFR) and vertical replenishment operations (VERTREP)

5. A lighting system to signify any unacceptable landing condition aboard the ship

6. Various other lighting systems to aid the pilot in operating under the more demanding environmental conditions on nonaviation ships.

All components of the VLA (fig. 11-1) assist both the helicopter and the ship in completing the assigned mission.

HOMING BEACON

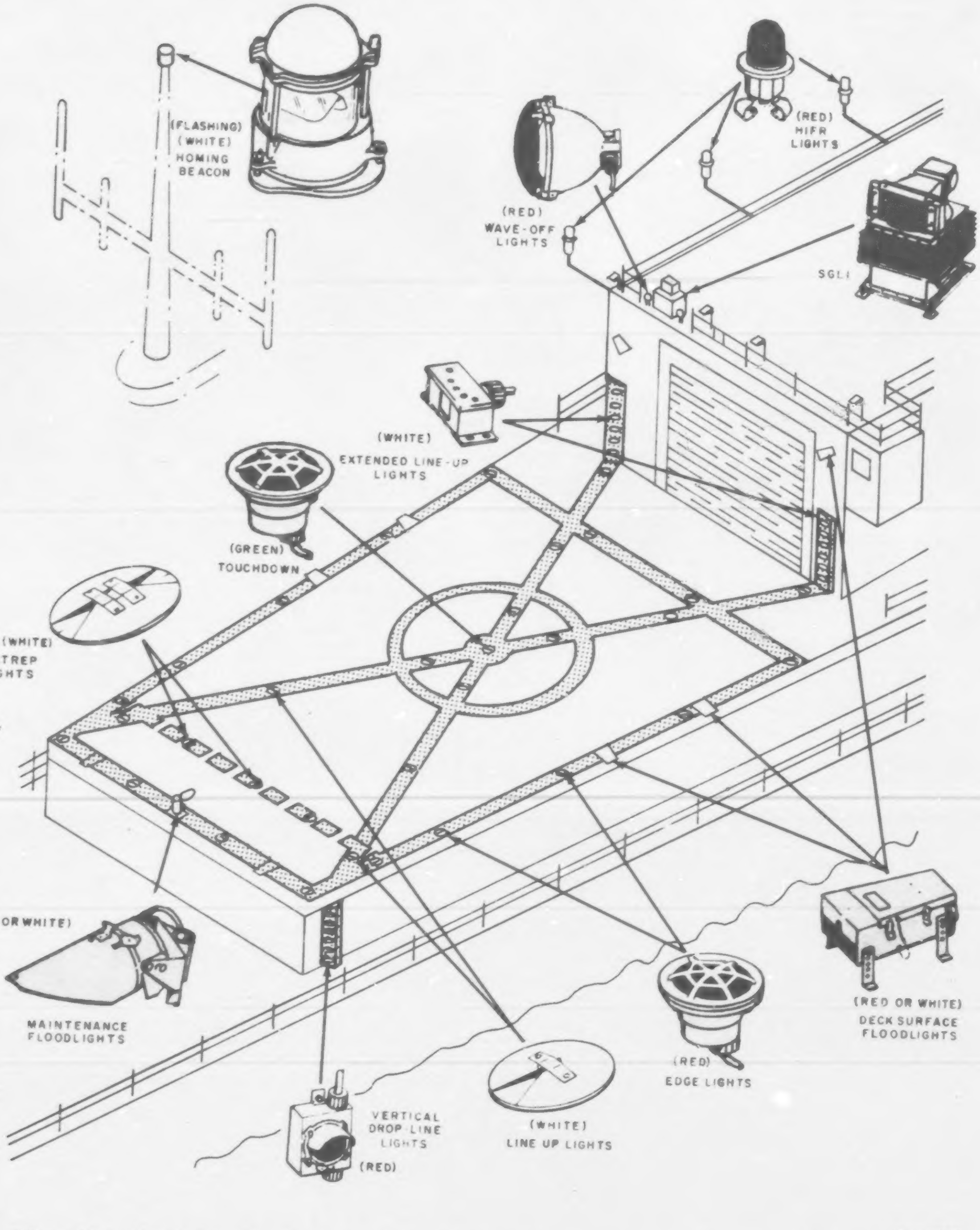
The Homing Beacon is a high intensity white lamp located on the main mast or high on the superstructure. It should be visible for at least 330° in azimuth. The beacon has a minimum effective intensity of 1500 candles over a span of 7° in elevation and produces approximately 90 flashes per minute. The intensity of the beacon light can be varied from blackout to full intensity by a dimmer control on the lighting control panel. The homing beacon is wired in two circuits: the motor which turns the reflector is wired to a fixed-voltage circuit (115 volts), while the lamp (150 watt) is wired through a stepdown transformer (115/32 volts) to a variable voltage dimming circuit.

STABILIZED GLIDE SLOPE INDICATOR SYSTEM

The Stabilized Glide Slope Indicator (SGSI) system (fig. 11-2) projects a tri-colored beam of light centered along a safe glide path to the ship. The upper sector of the light beam is green, the center portion (command path) is amber, and the lower sector is red. In operation, the helicopter pilot flies into (acquires) the beam and follows the command path to the ship. The glide slope indicator (GSI) is mounted on a stabilized platform which compensates for the ship's roll and pitch to keep the projected glide path steady.

The stabilized GSI system has six major components (fig. 11-3):

1. Electronic Enclosure Assembly
2. Remote Control Panel Assembly


(FLASHING)
(WHITE)
HOMING
BEACON
(RED)
HIFR
LIGHTS
(RED)
WAVE-OFF
LIGHTS
SGLI
(WHITE)
EXTENDED LINE-UP
LIGHTS
(GREEN)
TOUCHDOWN
(WHITE)
VERTREP
LIGHTS
(RED OR WHITE)
MAINTENANCE
FLOODLIGHTS
(RED OR WHITE)
DECK SURFACE
FLOODLIGHTS
(RED)
EDGE LIGHTS
VERTICAL
DROP-LINE
LIGHTS
(RED)
(WHITE)
LINE UP LIGHTS

111.171

Figure 11-1.—Typical VLA installations with flight deck and hangar on 0-1 level, dual landing approach.

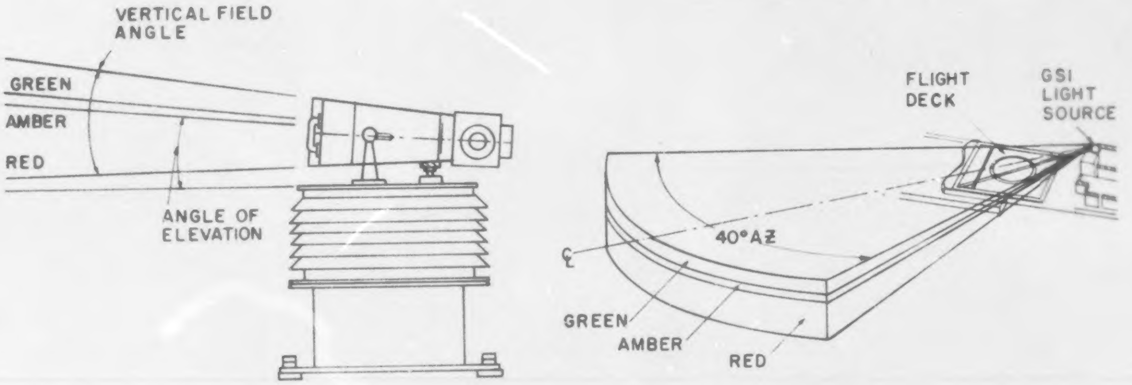

VERTICAL FIELD ANGLE
GREEN
AMBER
RED
ANGLE OF ELEVATION
FLIGHT DECK
GSI LIGHT SOURCE
40° AZ
℄
GREEN
AMBER
RED

Figure 11-2.–Glide slope indicator and light beam. 111.172

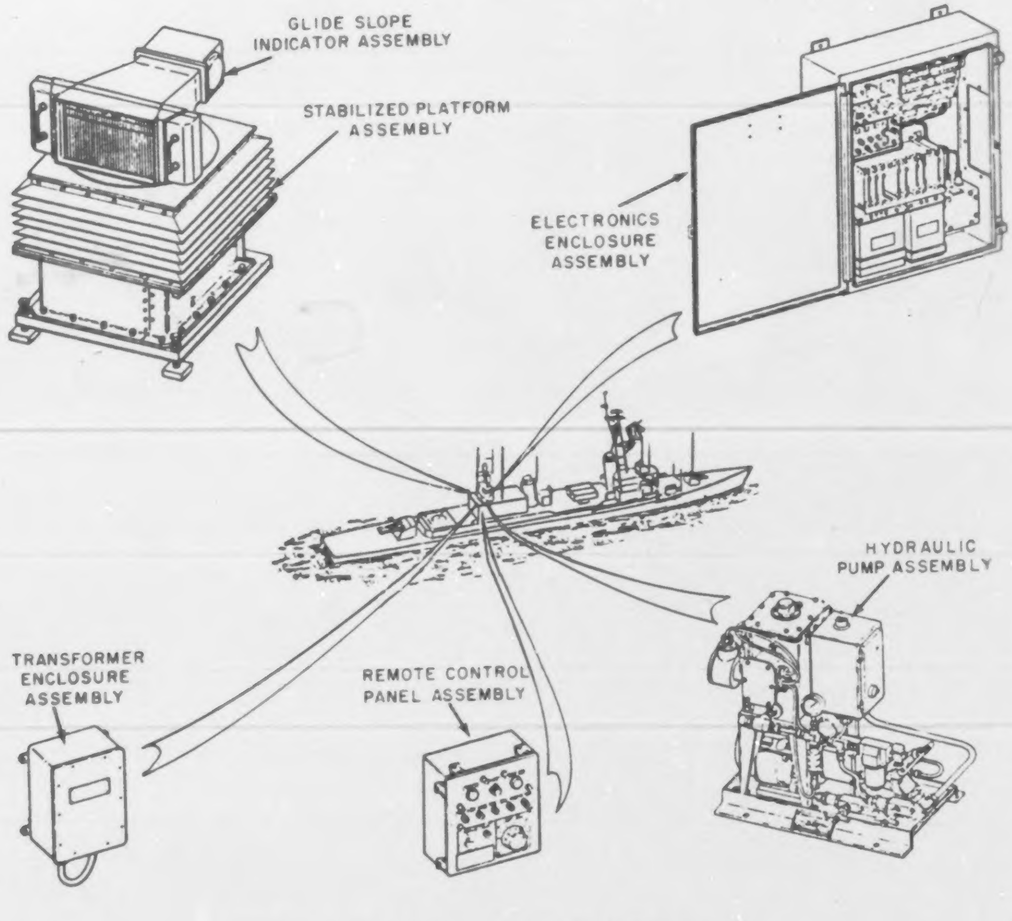
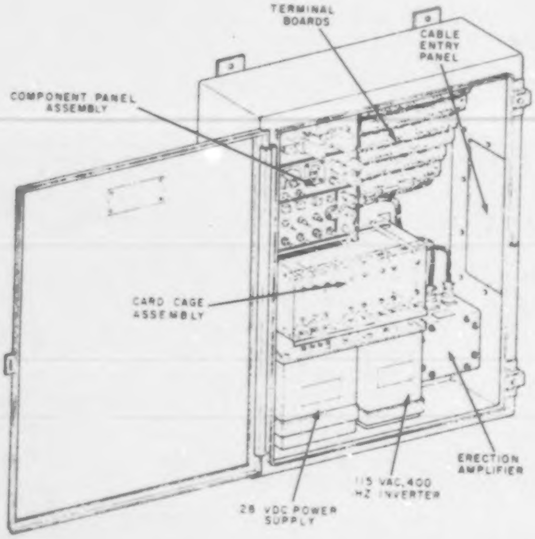

GLIDE SLOPE INDICATOR ASSEMBLY
STABILIZED PLATFORM ASSEMBLY
ELECTRONICS ENCLOSURE ASSEMBLY
HYDRAULIC PUMP ASSEMBLY
TRANSFORMER ENCLOSURE ASSEMBLY
REMOTE CONTROL PANEL ASSEMBLY

Figure 11-3.–Stabilized glide slope indicator system. 111.173

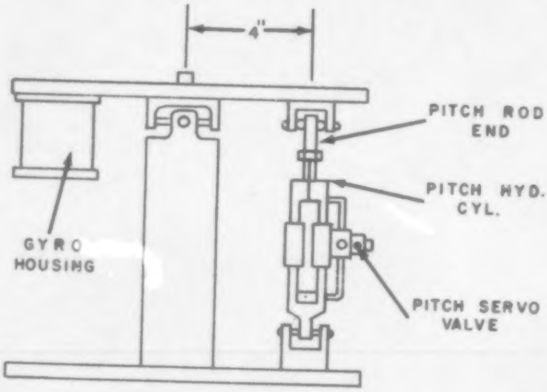
3. Hydraulic Pump Assembly
4. Transformer Assembly
5. Glide Slope Indicator
6. Stabilized Platform

Electronic Enclosure Assembly

The Electronic Enclosure Assembly (fig. 11-4) contains the circuits, amplifiers and other electrical and electronic components required to control the major components of the system. To understand the system operation, it is necessary to understand feedback control systems. A feedback control system compares an input signal with a reference signal and then generates an error signal. This error signal is then amplified and used to drive the output in a direction to reduce the error. This type feedback system is often referred to as a servo loop. A gyro (fig. 11-5), mounted on the stabilized platform, acts as the reference of the system. Since the gyro is stable, synchro transmitters located on the gimbals will sense any motion of pitch or roll. As the ship begins to pitch or roll, an error signal is developed by the synchro transmitter stators. Look at the block diagram in figure 11-6 and follow the path of the error signal through the electronic enclosure assembly. (The block diagram represents either the pitch or the roll control loops. They are identical electrically.) From the transmitter stators the error signal is sent to the gyro demodulator where the signal is changed from a.c. to d.c. The signal then goes through a stab-lock relay (described later) and is amplified as it moves through the servo amplifier which in turn operates the servo valve. The servo valve opens and allows hydraulic fluid to enter the hydraulic actuator (fig. 11-7), thereby leveling the platform and thus cancelling the error signal. When this occurs, a READY light is actuated on the remote control panel. If the system develops a malfunction and the error signal is not cancelled, an error-sensing circuit will light the NOT READY light on the remote control panel and turn off the glide slope indicator.

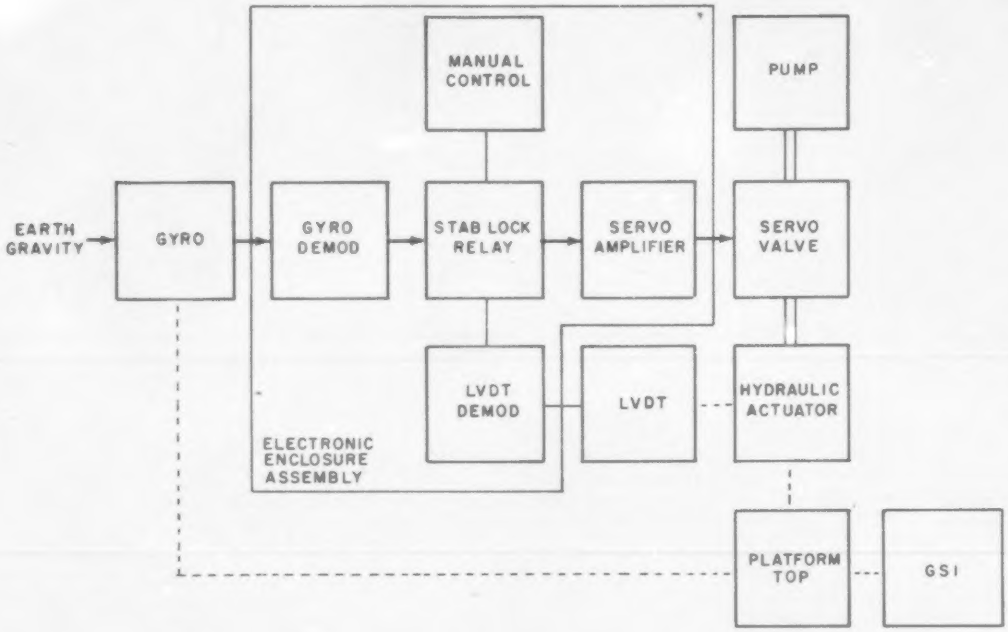


111.174
Figure 11-4.—Electronic enclosure assembly.



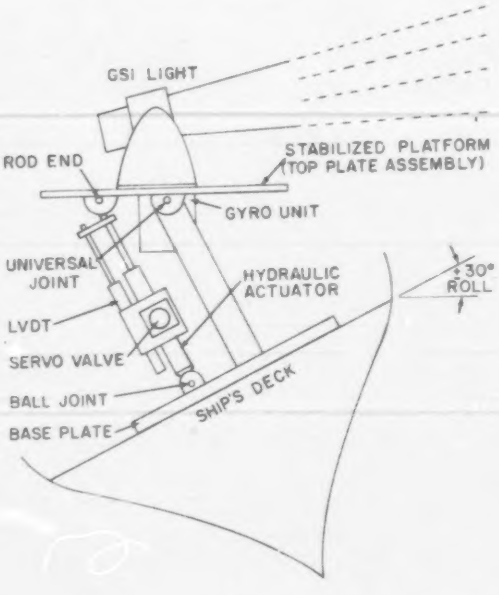
111.175
Figure 11-5.—Platform pitch drive.

In the previous paragraph we discussed the normal mode of operation in the electronics portion of the system. The stabilization lock feature (stab-lock relay) tests and aligns the GSI. Referring to figure 11-8, you will see a stab-lock


EARTH GRAVITY
GYRO
GYRO DEMOD
MANUAL CONTROL
STAB LOCK RELAY
LVDT DEMOD
SERVO AMPLIFIER
LVDT
PUMP
SERVO VALVE
HYDRAULIC ACTUATOR
ELECTRONIC ENCLOSURE ASSEMBLY
PLATFORM TOP
GSI

111.176

Figure 11-6.—Block diagram—stabilization circuits.


GSI LIGHT
ROD END
STABILIZED PLATFORM (TOP PLATE ASSEMBLY)
GYRO UNIT
UNIVERSAL JOINT
HYDRAULIC ACTUATOR
30° ROLL
LVDT
SERVO VALVE
BALL JOINT
BASE PLATE
SHIP'S DECK

111.177

Figure 11-7.—Stabilized platform assembly—functional diagram.

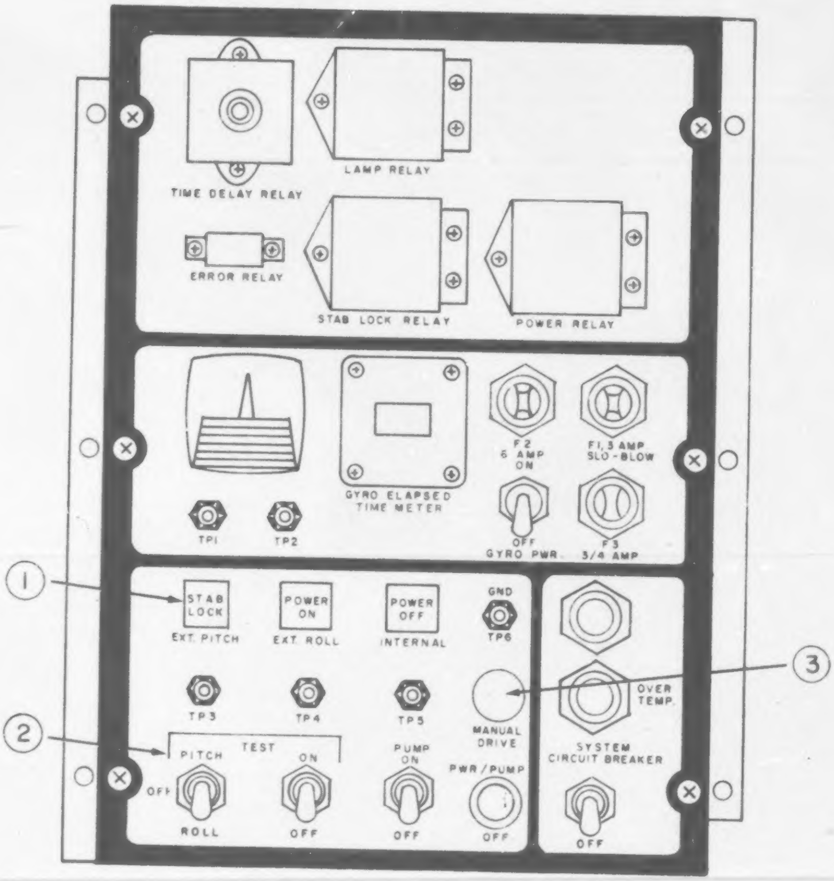

TIME DELAY RELAY
LAMP RELAY
ERROR RELAY
STAB LOCK RELAY
POWER RELAY
GYRO ELAPSED TIME METER
F2 6 AMP
ON
OFF
GYRO PWR.
F1, 3 AMP SLO-BLOW
F3 3/4 AMP
TP1
TP2
①
STAB LOCK
EXT. PITCH
POWER ON
EXT. ROLL
POWER OFF
INTERNAL
GND
TP6
③
TP3
TP4
TP5
MANUAL DRIVE
OVER TEMP.
SYSTEM CIRCUIT BREAKER
②
TEST
PITCH
OFF
ROLL
ON
OFF
PUMP ON
OFF
PWR/PUMP
OFF
OFF

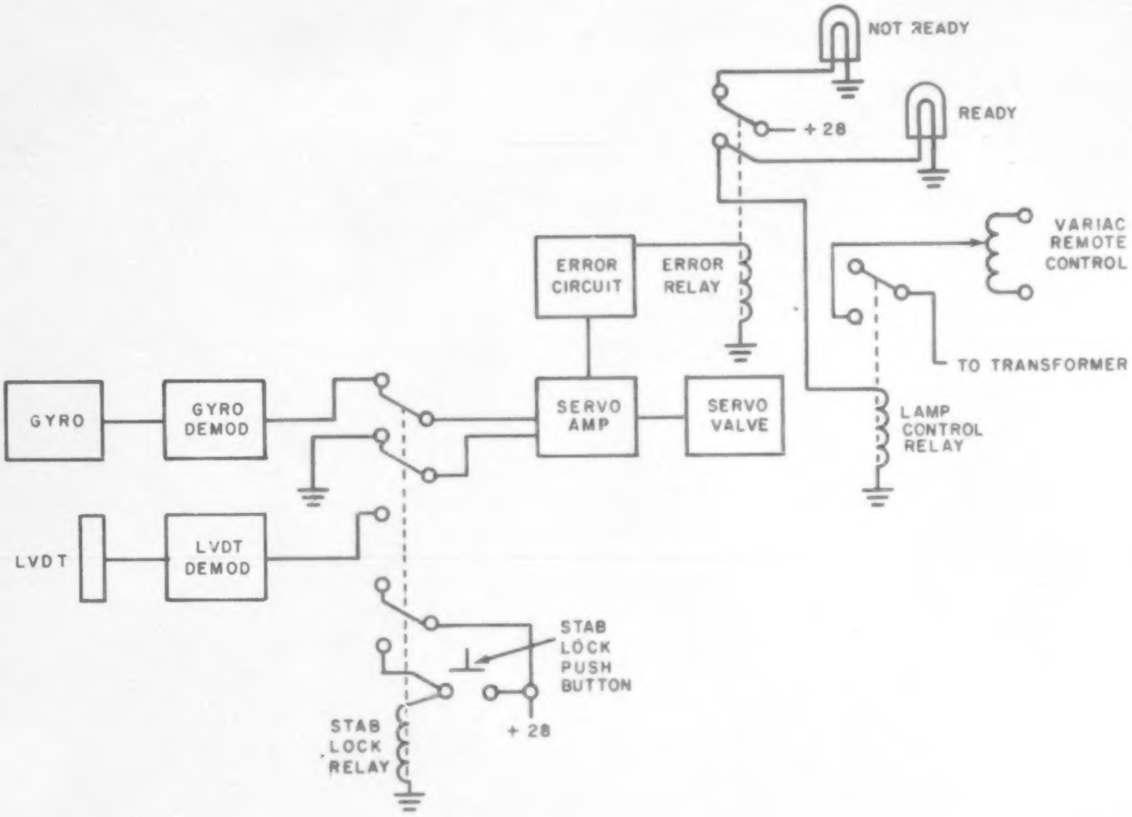
Figure 11-8.—Components panel assembly (located in electronics enclosure assembly).

111.178

push button ① and two test switches on-off ②, one of which is pitch-off-roll. As previously mentioned, the error signal in the normal mode goes through a stab-lock relay. When the stab-lock button is pushed, the normal error signal supplied from the gyro is stopped at this point. Look at figure 11-9. When the stab-lock button is pushed, the error signal comes from the linear voltage differential transformer (LVDT) when the test switch is in the off position. The core of the LVDT is mechanically attached to the hydraulic actuator which levels the platform. As the actuator moves, the core also moves, thereby supplying a signal proportional to the amount of roll or pitch. These signals can be measured to aid in the maintenance and alignment of the system. Provisions are also made to drive the platform manually using the test switches and the manual drive potentiometer (③ in fig. 11-8 and fig. 11-10).

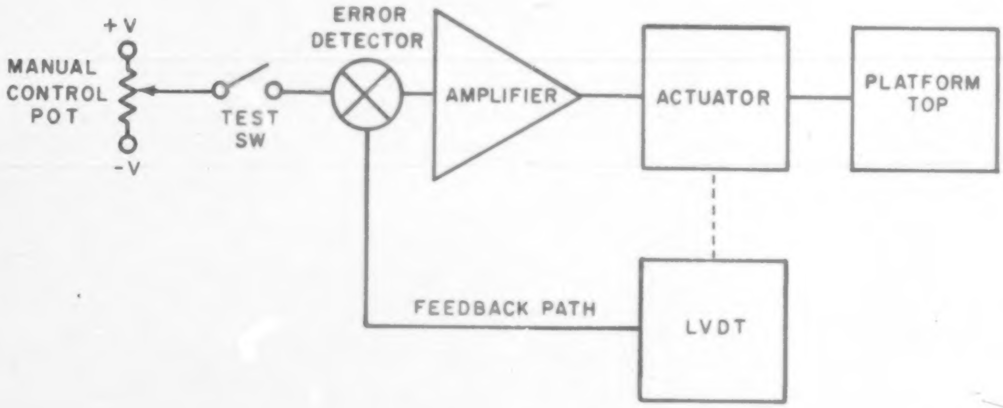
Remote Control Panel Assembly

The Remote Control Panel (fig. 11-11) is located in the flight operations control room. This panel provides control and indicators for operating and monitoring the SGSI from a remote location. It contains the READY and NOT READY lights described previously. The


NOT READY
READY
+ 28
VARIAC
REMOTE
CONTROL
ERROR
CIRCUIT
ERROR
RELAY
TO TRANSFORMER
GYRO
GYRO
DEMOD
SERVO
AMP
SERVO
VALVE
LAMP
CONTROL
RELAY
LVDT
LVDT
DEMOD
STAB
LOCK
PUSH
BUTTON
STAB
LOCK
RELAY
+ 28

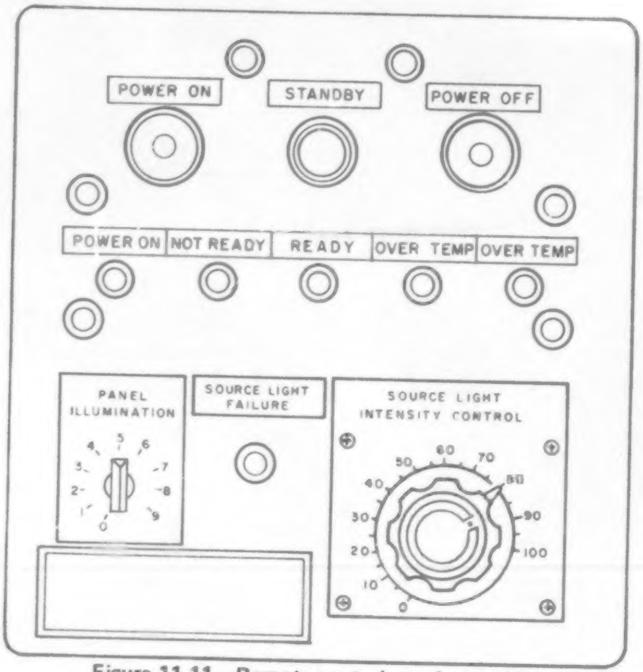
111.179

Figure 11-9.—Stabilization control circuits—signal flow.


+V
MANUAL
CONTROL
POT
-V
TEST
SW
ERROR
DETECTOR
AMPLIFIER
ACTUATOR
PLATFORM
TOP
FEEDBACK PATH
LVDT

111.180

Figure 11-10.—LVDT servo loop.



111.181

Figure 11-11.—Remote control panel assembly.

panel also contains two OVERTEMP lights to indicate when the hydraulic fluid is heated to a temperature higher than 135° F ±5°; a source failure light to indicate that one or more of the GSI source lights are burned out; a variable transformer to control the intensity of GSI light; and a panel illumination control. A standby light will be energized when the main switch on the electronic enclosure assembly is on.

Hydraulic Pump Assembly

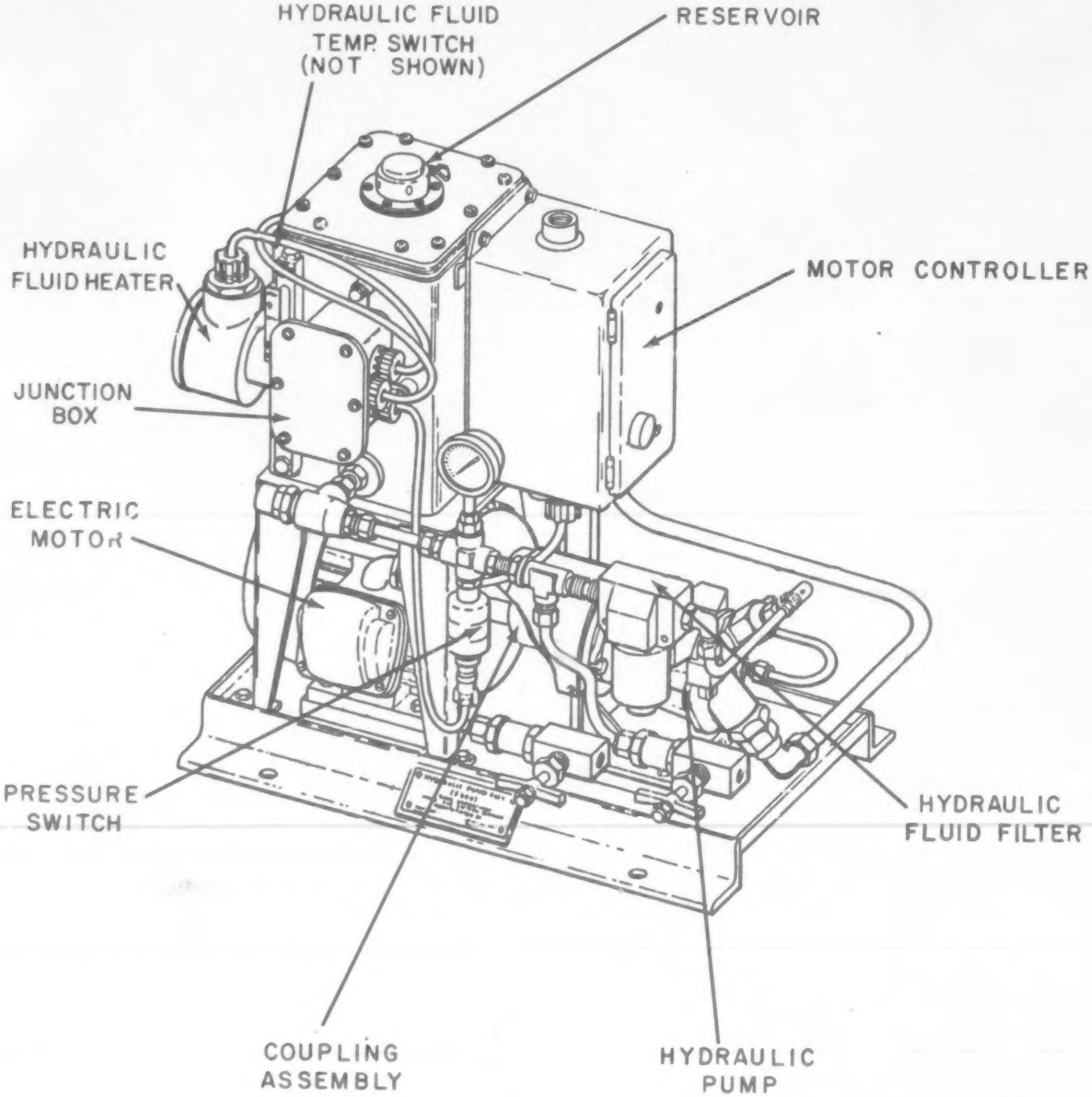
The Hydraulic Pump Assembly (fig. 11-12) is located as close as possible to the stabilized platform. It provides hydraulic fluid at 1400 psi to the hydraulic actuator on the stabilized platform. The motor and controller operate on 440 V 3 ϕ received from normal ship's power supply. The temperature switches (not shown) operate the HIGH TEMP light on the remote control panel. Also, a pressure switch in the hydraulic pump discharge line will close at 1200 psi. If not closed, the pressure switch will deenergize the electronic panel assembly on low oil pressure. Hydraulic fluid heaters in the oil reservoir maintain the temperature at approximately 90° F ±5°.

Transformer Assembly

The Transformer Assembly is located as close as possible to the stabilized platform. Its purpose is to step down the voltage for the source light (GSI) from 155 VAC to 18.5 VAC.

Glide Slope Indicator (GSI)

The Glide Slope Indicator (fig. 11-13A) is a cell assembly made up of three main sections—the lamp house assembly, the light tunnel, and the temperature control section. The lamp house assembly (fig. 11-13B) contains three source lights, a vent fan to cool the section, an optical lens (not shown), reflectors, etc. The light tunnel provides space for the focal length of the lens to be utilized. The temperature control section (fig. 11-13C)


HYDRAULIC FLUID TEMP. SWITCH (NOT SHOWN)
RESERVOIR
HYDRAULIC FLUID HEATER
MOTOR CONTROLLER
JUNCTION BOX
ELECTRIC MOTOR
PRESSURE SWITCH
HYDRAULIC FLUID FILTER
COUPLING ASSEMBLY
HYDRAULIC PUMP

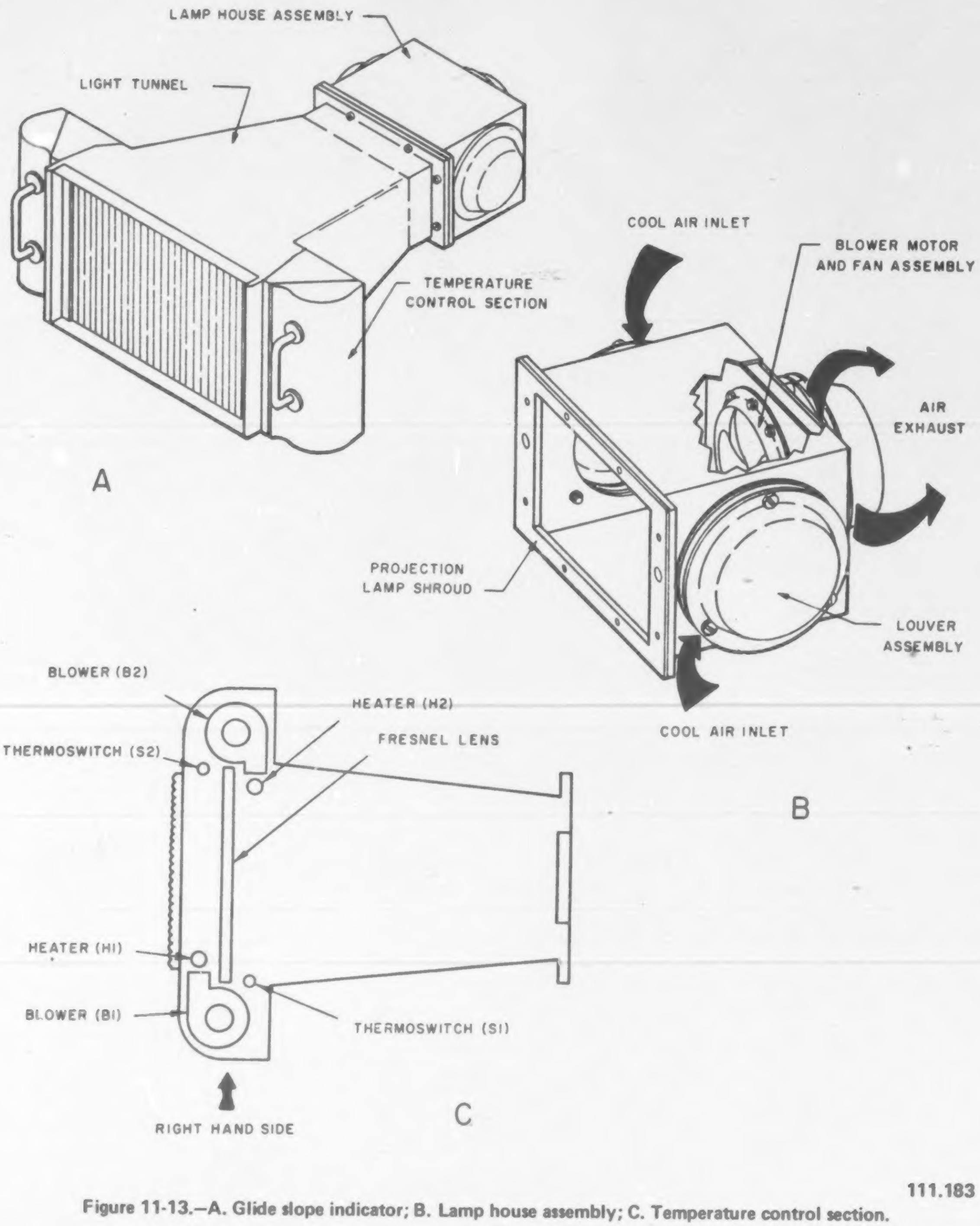
111.182

Figure 11-12.–Hydraulic pump assembly.

contains the fresnel lens which is sensitive to temperature. To maintain constant temperature, two heaters, each having a blower, are mounted on either side of the cell assembly. Each heater is controlled by a thermostat which maintains the temperature at 100° F ±3°. The blowers recirculate the heated air throughout the cell assembly.

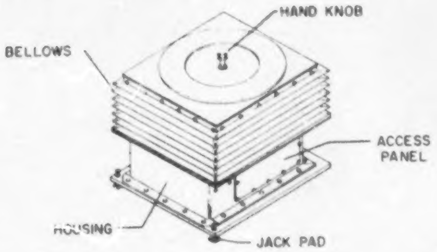
Stabilized Platform Assembly

The Stabilized Platform Assembly (fig. 11-14), which will remain level despite the pitch


LAMP HOUSE ASSEMBLY
LIGHT TUNNEL
TEMPERATURE CONTROL SECTION
A
COOL AIR INLET
BLOWER MOTOR AND FAN ASSEMBLY
AIR EXHAUST
PROJECTION LAMP SHROUD
LOUVER ASSEMBLY
COOL AIR INLET
B
BLOWER (B2)
HEATER (H2)
THERMOSWITCH (S2)
FRESNEL LENS
HEATER (H1)
BLOWER (B1)
THERMOSWITCH (S1)
RIGHT HAND SIDE
C

111.183

Figure 11-13.—A. Glide slope indicator; B. Lamp house assembly; C. Temperature control section.


HAND KNOB
BELLOWS
ACCESS PANEL
HOUSING
JACK PAD

111.184

Figure 11-14.–Stabilized platform assembly.

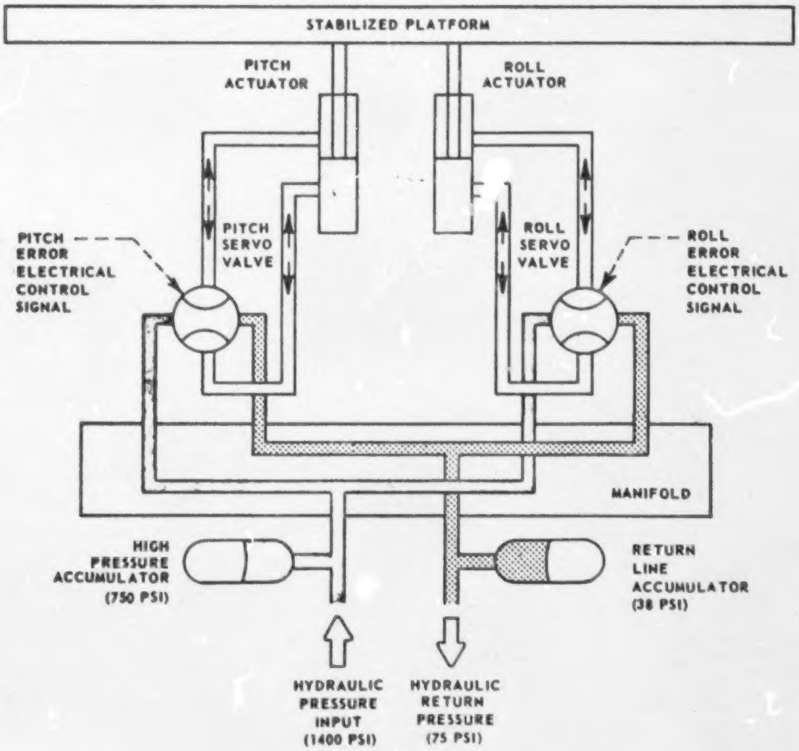
and roll attitude of the ship, provides a mount for the GSI. The assembly, shown in figure 11-15, consists of a stabilized platform attached to two hydraulic actuators (pitch and roll) which maintain the platform level at all times. The block diagram in figure 11-16 shows the complete system interconnected.

EDGE LIGHTS

The edge lights outline the periphery of the obstruction-free helicopter deck area with a minimum of four lights along each edge of the area. Edge lights are red omnidirectional lamps which can be seen in any direction above deck level. They are connected to the low voltage side of a 115/12 volt stepdown transformer. The 115 volt side of each transformer (one transformer per light fixture) is connected to a motor-driven variable transformer which controls the intensity of the lights.

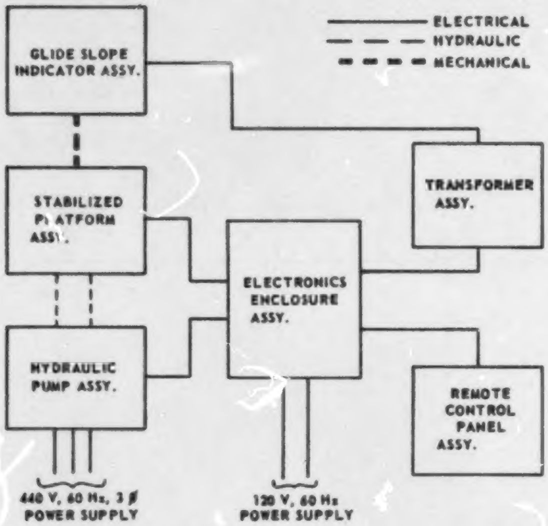
LINE-UP LIGHTS

The Line-Up Lights are white and flash in sequence. They are installed on the deck along the line-up line for deck landing. Line-up lights


STABILIZED PLATFORM
PITCH ACTUATOR
ROLL ACTUATOR
PITCH ERROR ELECTRICAL CONTROL SIGNAL
PITCH SERVO VALVE
ROLL SERVO VALVE
ROLL ERROR ELECTRICAL CONTROL SIGNAL
MANIFOLD
HIGH PRESSURE ACCUMULATOR (750 PSI)
RETURN LINE ACCUMULATOR (38 PSI)
HYDRAULIC PRESSURE INPUT (1400 PSI)
HYDRAULIC RETURN PRESSURE (75 PSI)

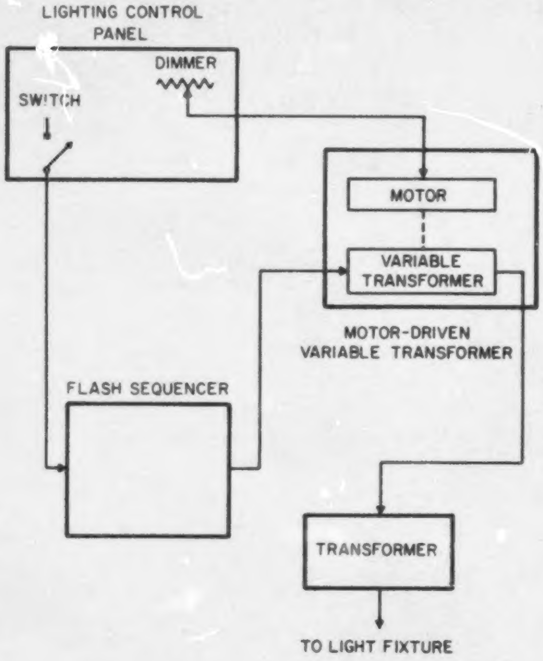
111.185

Figure 11-15.–Function diagram of the stabilized platform assembly.


ELECTRICAL
HYDRAULIC
MECHANICAL
GLIDE SLOPE INDICATOR ASSY.
STABILIZED PLATFORM ASSY.
HYDRAULIC PUMP ASSY.
TRANSFORMER ASSY.
ELECTRONICS ENCLOSURE ASSY.
REMOTE CONTROL PANEL ASSY.
440 V, 60 Hz, 3 ϕ POWER SUPPLY
120 V, 60 Hz POWER SUPPLY

111.186

Figure 11-16.—Stabilized glide slope indicator system—block diagram.


LIGHTING CONTROL PANEL
DIMMER
SWITCH
MOTOR
VARIABLE TRANSFORMER
MOTOR-DRIVEN VARIABLE TRANSFORMER
FLASH SEQUENCER
TRANSFORMER
TO LIGHT FIXTURE

111.187

Figure 11-17.—Simplified interconnection of line-up lights.

are either unidirectional or bidirectional dependent on the ship's landing capability. Each lamp is connected to the secondary side of a 115/6.5 volt stepdown transformer. The primary is connected to a motor-driven, variable transformer (intensity) and a flash sequencer (fig. 11-17).

FLASH SEQUENCER

The Flash Sequencer (fig. 11-18) is wired into the line-up lights to provide the helicopter pilot with additional visual cues and depth perception during night landing approach. The cam operated unit sequentially flashes 9 to 10 line-up lights. On ships with both port and starboard approach, the flash sequencer must be capable of producing flashes (strobing) of either port or starboard line-up lights as selected by controls on the lighting control panel.

EXTENDED LINE-UP LIGHTS

Extended Line-Up Lights are white lights installed at the forward end of the deck-installed line-up lights and extend above the flight-deck level. In other words, these lights merely extend the line-up lights forward to provide the helicopter pilot with final position information for the touchdown maneuver during night landing operations. The extended line-up lights are a minimum of six individual light fixtures either mounted vertically to a bulkhead or on a light bar assembly mounted to the flight deck. Each extended line-up light fixture is connected to a 6.5 volt secondary of a 120/6.5 volt stepdown transformer. The primaries of the transformers are connected to the same circuit as the deck-installed, line-up lights.

VERTICAL DROP-LINE LIGHTS

Vertical Drop-Line Lights are red and serve as an aft extension of the deck-installed line-up lights. The light bar assembly is installed

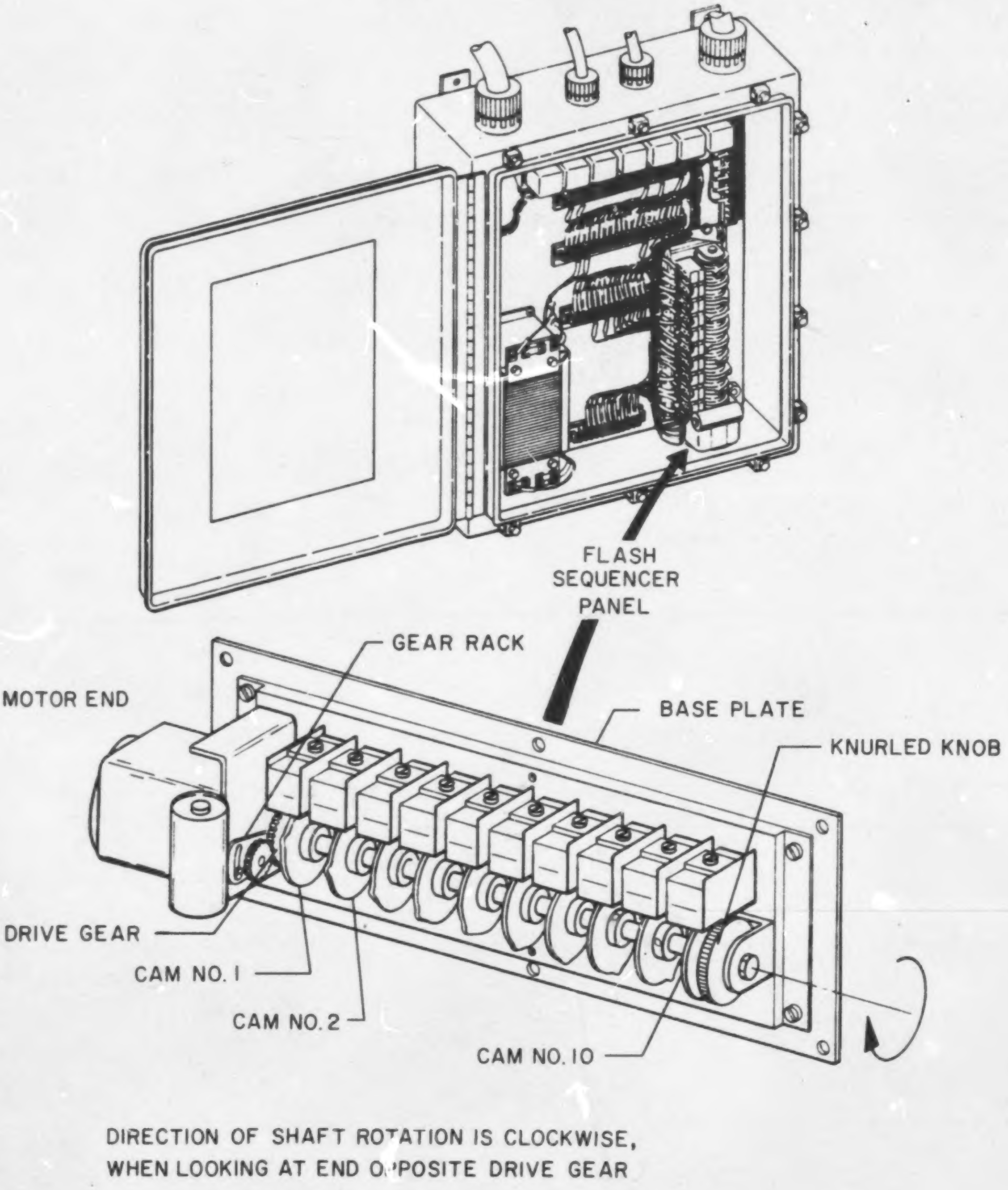

FLASH SEQUENCER PANEL
GEAR RACK
MOTOR END
BASE PLATE
KNURLED KNOB
DRIVE GEAR
CAM NO. 1
CAM NO. 2
CAM NO. 10
DIRECTION OF SHAFT ROTATION IS CLOCKWISE, WHEN LOOKING AT END OPPOSITE DRIVE GEAR
111.188

Figure 11-18.–Flash sequencer panel and timer assembly.

immediately aft of the landing line-up lights and contains four to six red lights which extend below the flight deck in the vertical plane. These lights provide the helicopter pilot with continuous line up during night approach when deck-installed line-up lights cannot be seen because of the ship's motion. The drop-line bar assembly operates from a single 120/12 volt stepdown transformer/enclosure assembly which is wired to a motor-driven, variable voltage transformer (dimmer).

TOUCHDOWN LIGHT

The Touchdown Light is a green, omnidirectional light located at the center of the touchdown circle to indicate to the pilot the desired landing spot. The light is wired to a 115/12-volt stepdown transformer, and its intensity is controlled by the same dimmer as the edge lights.

WAVE-OFF LIGHT SYSTEM

The Wave-Off Light (WOL) System (fig. 11-19) provides a visual cue to the pilot that landing conditions aboard the ship are unacceptable. The system consists of nine major components:

1. Master Control Panel Assembly
2. Two Remote Panel Assemblies
3. Two Plug In Junction Box Assemblies
4. Terminal Junction Box Assembly
5. Two Wave-Off Light Assemblies
6. Portable Switch

Master Control Panel

The Master Control Panel (fig. 11-20) is located in the flight control station. It functions to control the power for the WOL, houses the electronic circuitry to control intensity and flash rate of the WOL, permits operation of the WOL, and indicates which station has control.

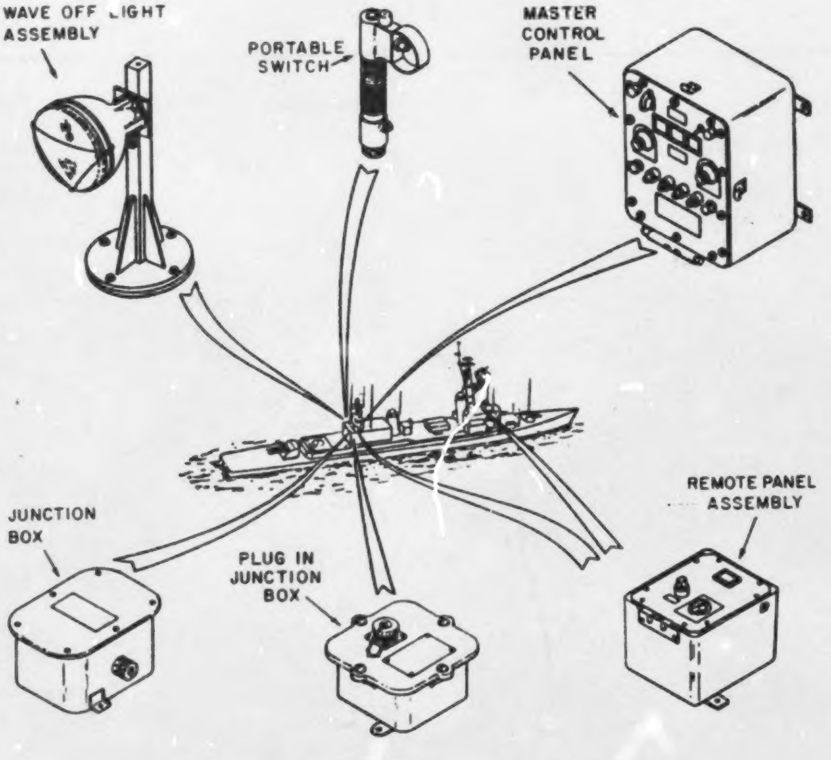
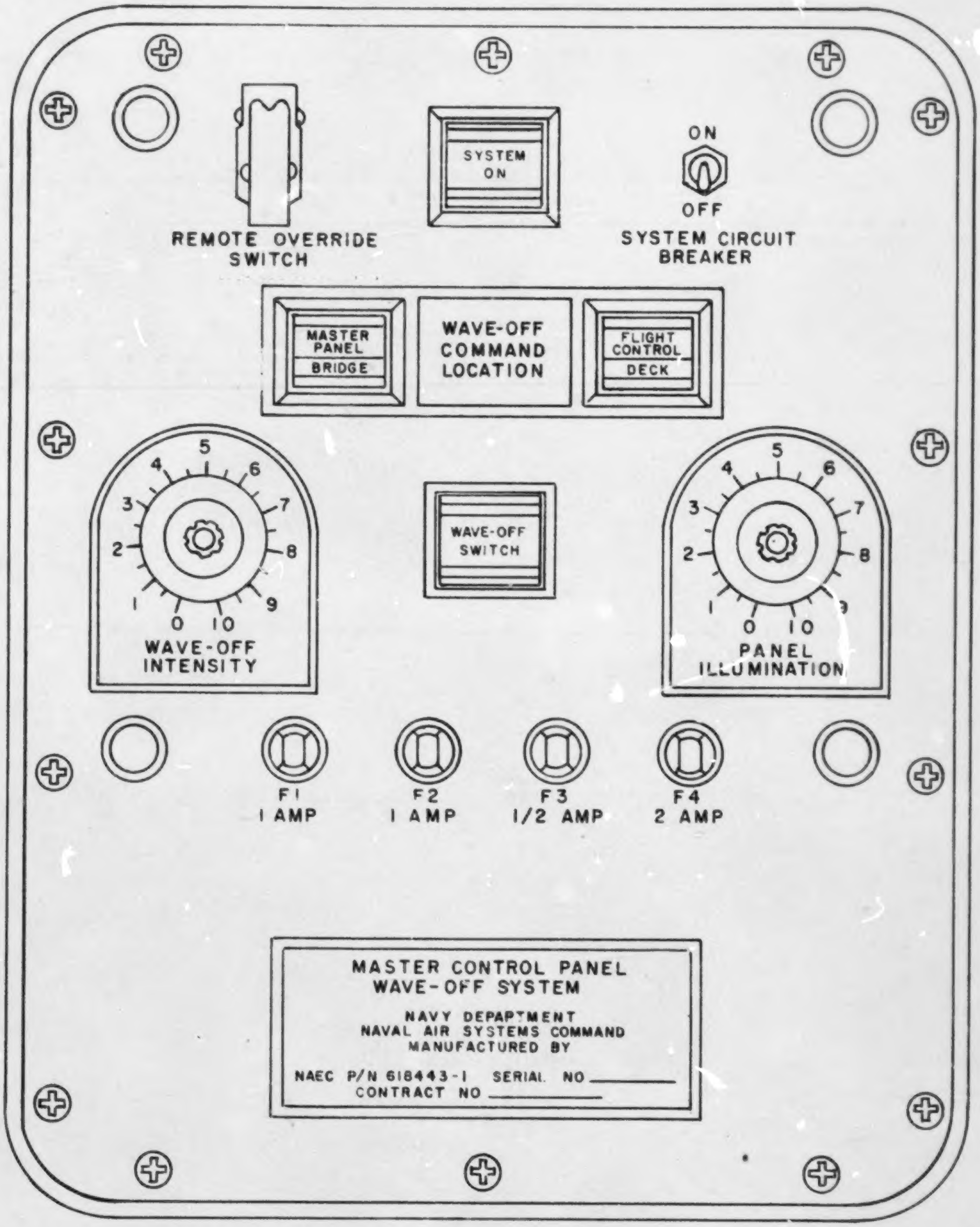


Figure 11-19.—Wave-off light system.


REMOTE OVERRIDE SWITCH
SYSTEM ON
ON
OFF
SYSTEM CIRCUIT BREAKER
MASTER PANEL
BRIDGE
WAVE-OFF COMMAND LOCATION
FLIGHT CONTROL
DECK
0 1 2 3 4 5 6 7 8 9 10
WAVE-OFF INTENSITY
WAVE-OFF SWITCH
0 1 2 3 4 5 6 7 8 9 10
PANEL ILLUMINATION
F1 1 AMP
F2 1 AMP
F3 1/2 AMP
F4 2 AMP
MASTER CONTROL PANEL
WAVE-OFF SYSTEM
NAVY DEPARTMENT
NAVAL AIR SYSTEMS COMMAND
MANUFACTURED BY
NAEC P/N 618443-1 SERIAL NO
CONTRACT NO

111.190

Figure 11-20.–Master control panel.

Remote Panel Assembly

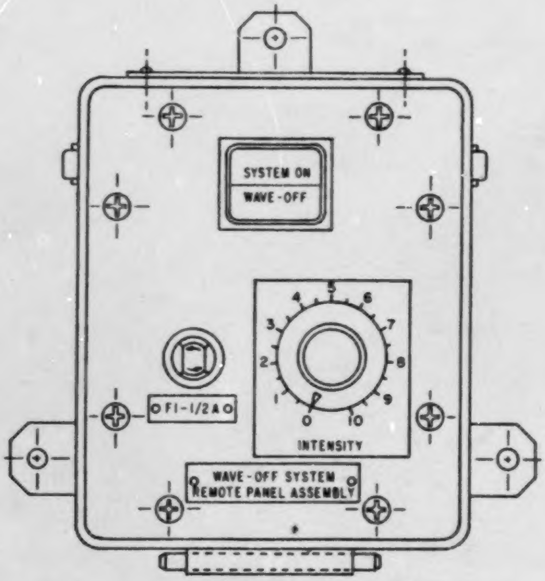
The Remote Panel Assembly (fig. 11-21) allows the WOL to be operated from remote stations located at the captain's bridge and flight control station.

Plug In Junction Box Assembly

Two plug in junction boxes are contained in one assembly. The junction boxes are located one on either side of the hangar door to permit plug in of a portable switch to operate the WOL on the flight deck.

Terminal Junction Box Assembly

The Terminal Junction Box Assembly contains the terminals for the connections to the WOL and the Master Control Panel.



111.191
Figure 11-21.—Remote panel assembly.

Wave-Off Light Assembly

The Wave-Off Lights are located one on either side of the GSI. Figure 11-22 shows interconnection of the WOL system.

FORWARD STRUCTURE/DECK SURFACE FLOODLIGHTS

Red or white floodlights are provided to illuminate any structure forward of the landing area and to provide greater depth perception to the pilot during night operations. At least two fixtures, one port and one starboard, must be installed and adjusted to illuminate the aft face of the hangar as well as structures forward of the landing area. Other fixtures are installed and adjusted to illuminate the landing area itself. These fixtures are connected to a motor-driven variable transformer (intensity). Each fixture is connected to the low voltage side of a separate 120/30 volt stepdown transformer.

MAINTENANCE FLOODLIGHTS

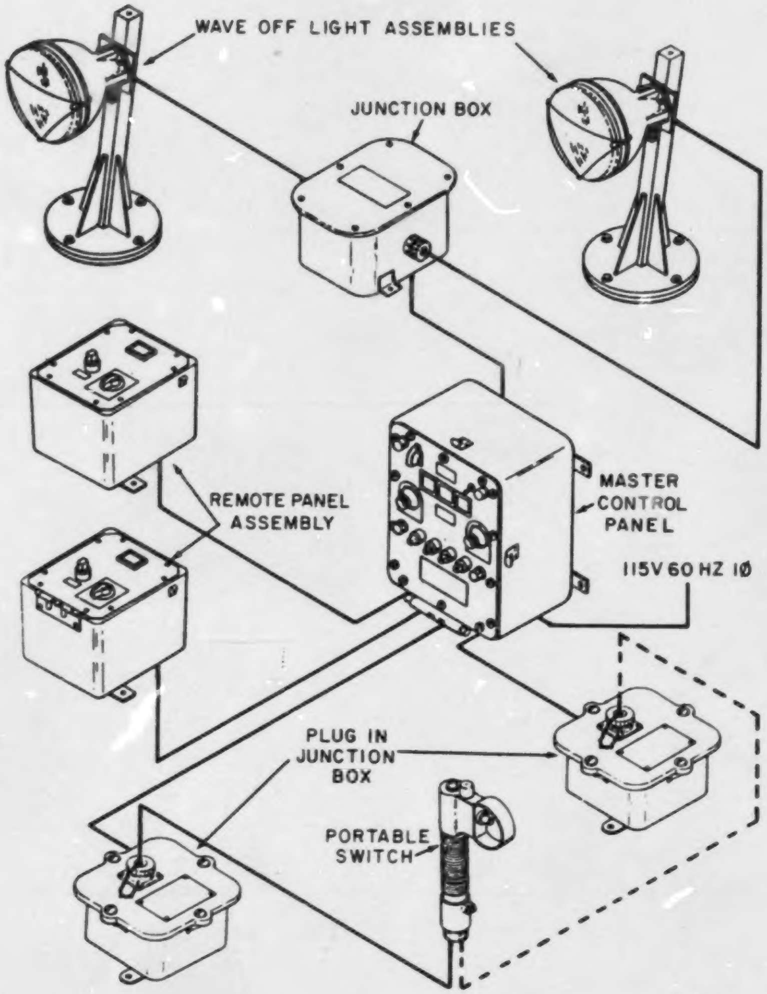
Red Maintenance Floodlights are required for night preflight and postflight maintenance. The floodlight assembly consists of a light fixture, lamp, red filter, on/off switch and support. The light is wired to the ship's 120-volt, 60-Hz, 1 ϕ power supply.

OVERHEAD FLOODLIGHTS

Red or white overhead floodlights provide illumination of the helicopter deck for support of night operations. These lights are mounted above the landing area and are connected to a motor-driven variable transformer.

HELICOPTER IN-FLIGHT REFUELING HEADING LIGHTS (HIFR)

Helicopter In-Flight Refueling Heading Lights are red and are required for helicopter refueling operations. These lights give the

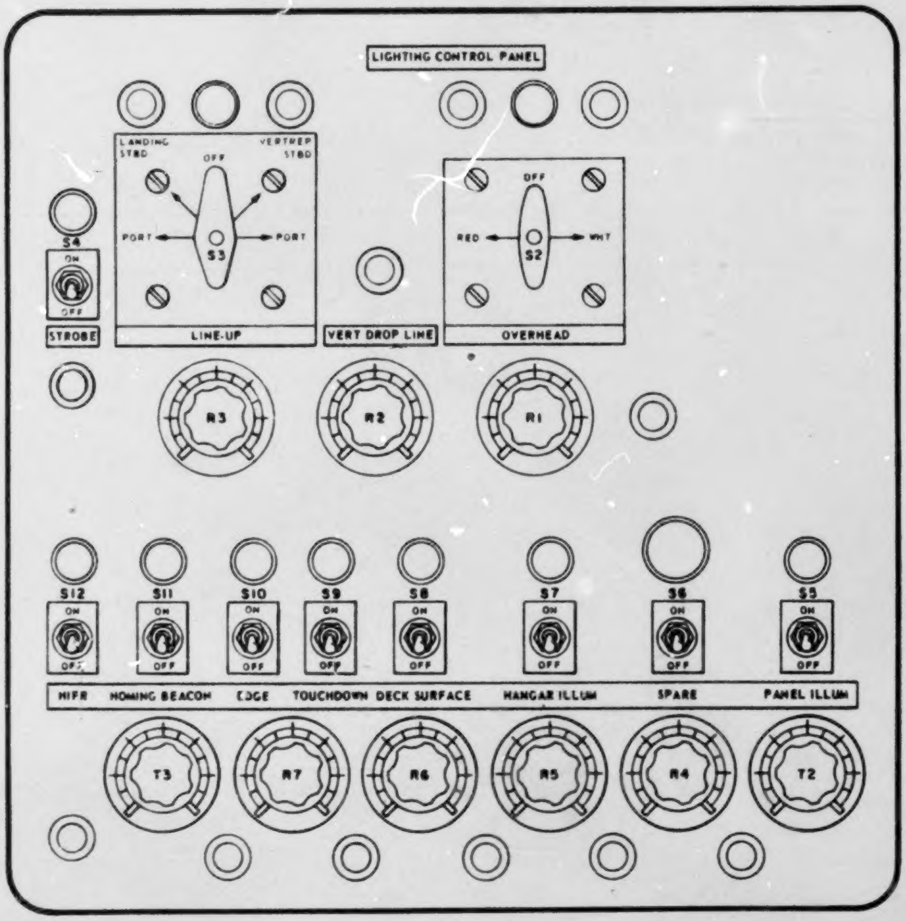

WAVE OFF LIGHT ASSEMBLIES
JUNCTION BOX
REMOTE PANEL ASSEMBLY
MASTER CONTROL PANEL
115V 60 HZ 1Ø
PLUG IN JUNCTION BOX
PORTABLE SWITCH

111.192

Figure 11-22.–Wave-off light system.

helicopter pilot a visual indication of the ship's heading at all times and provide a height reference during in-flight refueling operations.

Three red HIFR heading lights are installed forward to aft on the port side of the ship in a line parallel to the ship's centerline (heading). Spacing between the lights is approximately 20 feet, beginning outside the rotor clearance distance and extending forward. All HIFR heading lights are installed at the same height, approximately 30 to 40 feet above the ship's waterline. All lights are controlled by a single on/off switch located on the lighting control panel, and are a standard watertight assembly consisting of a lighting fixture, red globe, and a 115-volt, 50-watt rough service lamp.


LIGHTING CONTROL PANEL
LANDING STBD
OFF
VERTREP STBD
PORT
S3
PORT
LINE-UP
S4
ON
OFF
STROBE
VERT DROP LINE
OFF
RED
S2
WHT
OVERHEAD
R3
R2
R1
S12
S11
S10
S9
S8
S7
S6
S5
ON
OFF
HIFR
HOMING BEACON
EDGE
TOUCHDOWN
DECK SURFACE
HANGAR ILLUM
SPARE
PANEL ILLUM
T3
R7
R6
R5
R4
T2

111.193

Figure 11-23.—Lighting control panel.

VERTICAL REPLENISHMENT (VERTREP) LIGHTS

VERTREP line-up lights are bidirectional fixtures for VERTREP/hover approaches and they form an athwartship line-up path at approximately 8- to 12-foot intervals. Spacing between lights is uniform and such that the pilot's view of the lights is not obstructed during the helicopter's approach. When installed in landing areas equipped with landing approach line-up lights, the VERTREP line-up lights are connected to the same dimmer as the landing approach line-up lights. The circuit switching arrangement, however, precludes the simultaneous energizing of both the landing approach line-up lights and the VERTREP/hover line-up lights.

LIGHTING CONTROL PANEL

The Lighting Control Panel (fig. 11-23) that controls the lights in the VLA package are installed on all ships which conduct helicopter operations at night. This control panel is located at the helicopter control station and consists of switches, dimmers, and red indicator lamps. The

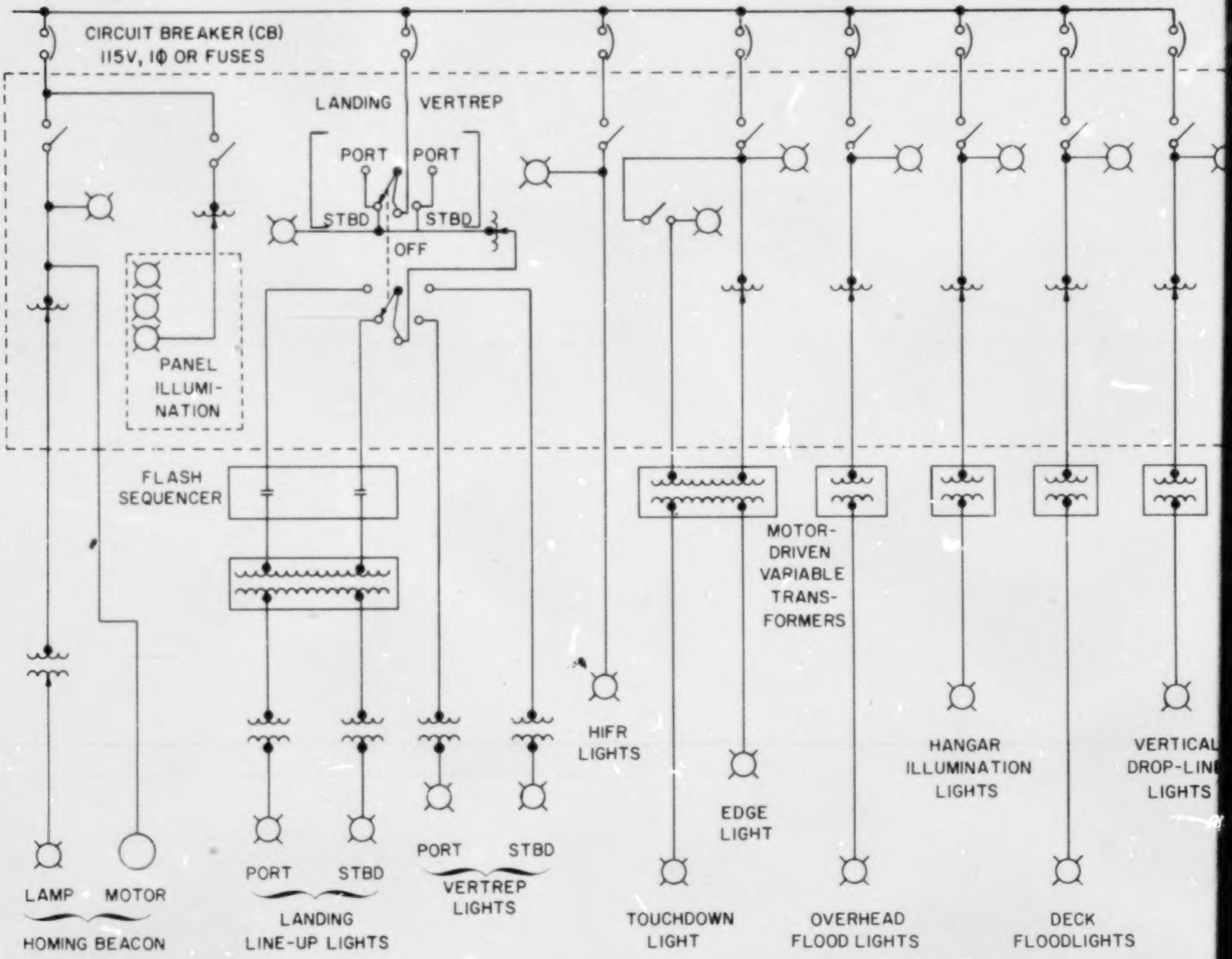
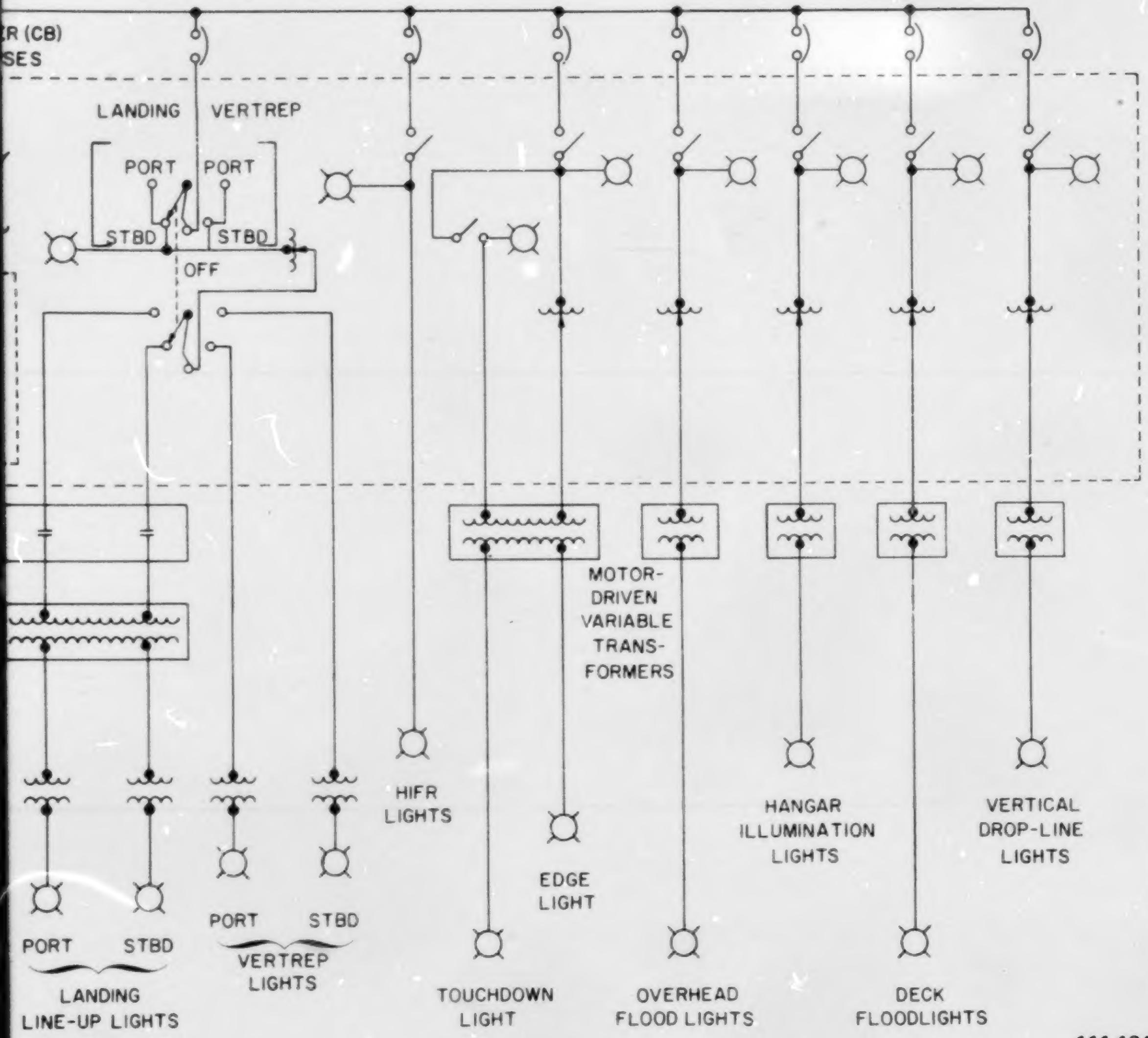
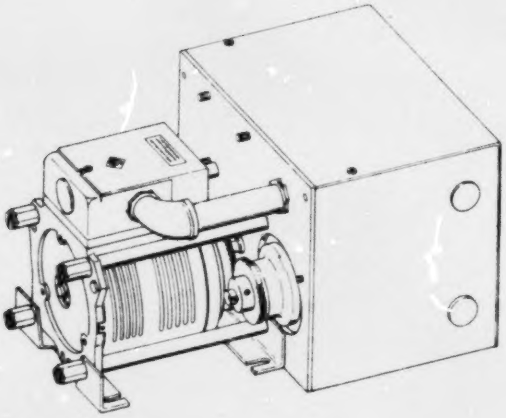

CIRCUIT BREAKER (CB)
115V, 1Φ OR FUSES
LANDING
VERTREP
PORT
PORT
STBD
STBD
OFF
PANEL
ILLUMI-
NATION
FLASH
SEQUENCER
MOTOR-
DRIVEN
VARIABLE
TRANS-
FORMERS
HIFR
LIGHTS
EDGE
LIGHT
HANGAR
ILLUMINATION
LIGHTS
VERTICAL
DROP-LIN
LIGHTS
LAMP
MOTOR
HOMING BEACON
PORT
STBD
LANDING
LINE-UP LIGHTS
PORT
STBD
VERTREP
LIGHTS
TOUCHDOWN
LIGHT
OVERHEAD
FLOOD LIGHTS
DECK
FLOODLIGHTS

Figure 11-24.—Simplified line diagram of the lighting control panel.


R (CB)
SES
LANDING
VERTREP
PORT
PORT
STBD
STBD
OFF
MOTOR-DRIVEN VARIABLE TRANS-FORMERS
HIFR LIGHTS
EDGE LIGHT
HANGAR ILLUMINATION LIGHTS
VERTICAL DROP-LINE LIGHTS
PORT
STBD
PORT
STBD
VERTREP LIGHTS
LANDING LINE-UP LIGHTS
TOUCHDOWN LIGHT
OVERHEAD FLOOD LIGHTS
DECK FLOODLIGHTS

111.194

Figure 11-24.—Simplified line diagram of the lighting control panel.



111.195

Figure 11-25.—Motor-driven variable transformer.

dimmers are variable autotransformers mounted in the control panel of remotely located autotransformers controlled by potentiometers in the control panel. The lighting control panel requires input power at 120 volt, 60 Hz and is designed to accommodate the applicable light equipment discussed in the preceding paragraphs. Figure 11-24 is a simplified line diagram of the lighting control panel.

MOTOR-DRIVEN VARIABLE TRANSFORMERS

Motor-driven remote variable transformers (fig. 11-25) are used in the VLA lighting control system to control the intensity of the various lights. There are four 10-ampere and two 22-ampere transformers in the system. The

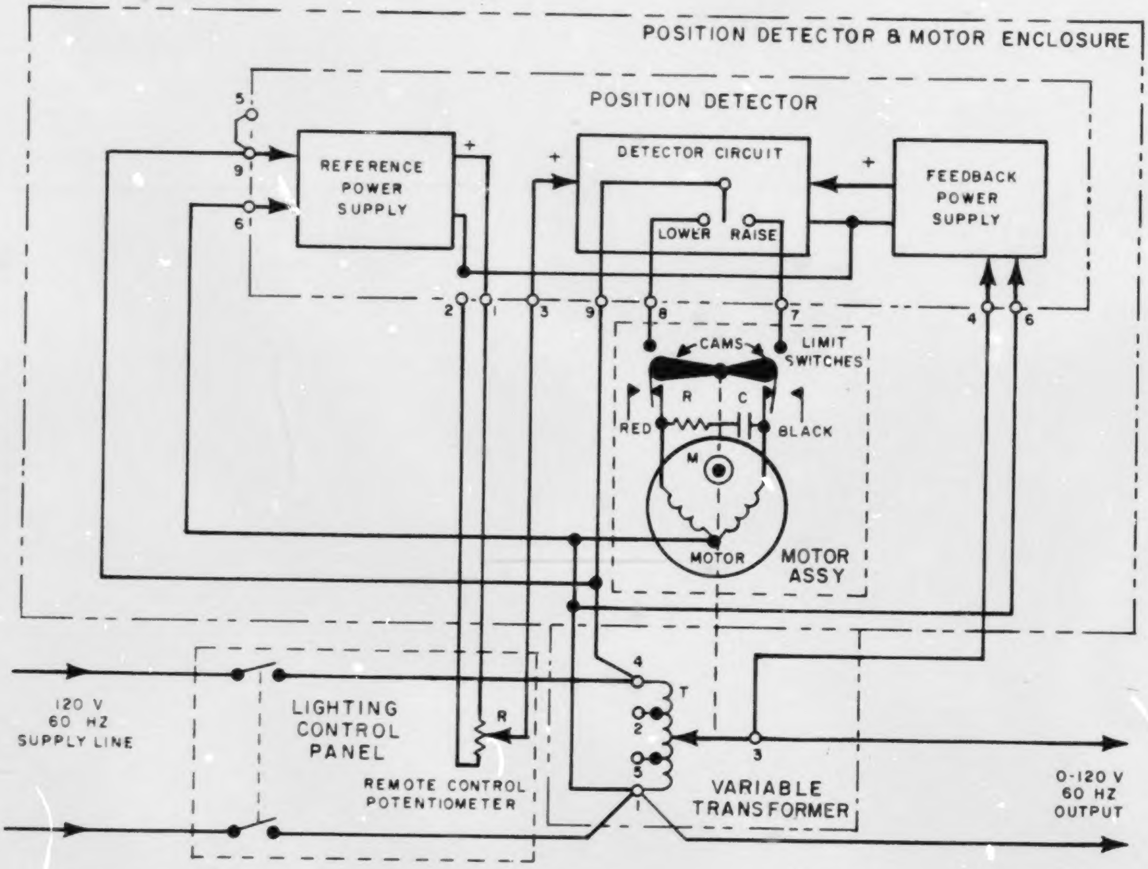

POSITION DETECTOR & MOTOR ENCLOSURE
POSITION DETECTOR
5
9
6
REFERENCE POWER SUPPLY
+
+
DETECTOR CIRCUIT
LOWER
RAISE
+
FEEDBACK POWER SUPPLY
2
1
3
9
8
7
4
6
CAMS
LIMIT SWITCHES
R
C
RED
BLACK
M
MOTOR
MOTOR ASSY
120 V 60 HZ SUPPLY LINE
LIGHTING CONTROL PANEL
R
REMOTE CONTROL POTENTIOMETER
4
T
2
3
5
1
VARIABLE TRANSFORMER
0-120 V 60 HZ OUTPUT

Figure 11-26.—Motor-driven remote variable transformer circuit diagram.

111.196

22-ampere transformers are used with the overhead and deck surface floodlights and the 10-ampere transformers are used with the following lights:

1. Hangar illumination floodlights
2. Line-up lights
3. Vertical drop-line lights
4. Edge and touchdown lights

Input power is applied to the variable transformer, and the controlled 0 to 120 VAC output is connected to the lights (fig. 11-26). The transformer wiper (secondary) is moved by the synchronous motor which is controlled by the potentiometer in the lighting control panel. The detector circuit in the position detector determines from the setting of the remote control potentiometer whether the motor turns in a direction to raise or lower the output voltage.

The reference power supply in the position detector converts a.c. input voltage to d.c., and the potentiometer in the control panel determines the magnitude of d.c. reference voltage sent to the detector circuit. The feedback power supply in the position detector converts the a.c. output voltage from the variable transformer to a proportional d.c. voltage which is also sent to the detector circuit.

The detector circuit consists of a comparator and solid state switches (TRIACS) which energize either the clockwise (LOWER) or counterclockwise (RAISE) winding of the drive motor. The drive motor rotates the wiper shaft on the transformer in the proper direction until the feedback voltage equals the reference, and the motor stops at a position corresponding to the desired light intensity. Cam-operated limit switches open the motor circuit and prevent the motor from driving the wiper on the transformer beyond the upper and lower stops.

MAINTENANCE REQUIREMENTS

The VLA system contains many electrical and electronic components which require both preventive and corrective maintenance. The components that we have discussed in this chapter contain many motors, controllers, blowers, heaters, pressure switches, and lighting fixtures that are exposed to weather. The electronic portions are solid state and are primarily on printed circuit cards. As an Electrician's Mate you can realize some of the problems which will be encountered both with electrical and electronic parts. It is of utmost importance that you follow all PMS requirements carefully to keep all portions of this system operating effectively. When performing any corrective action, always refer to the manufacturer's technical manuals.

APPENDIX I

TEMPERATURE CONVERSION TABLE

Numbers in the center column (between those marked C and F) refer to temperature, either Centigrade or Fahrenheit, which it is desired to convert into the other scale. To convert from Fahrenheit to Centigrade find equivalent temperature in left hand column marked C; in like manner find equivalent temperature in right hand column when converting from Centigrade to Fahrenheit. Example: 50 F. is 10 C.; 50 C. is 122 F.

C.		F.	C.		F.	C.		F.	C.		F.
−12.2	**10**	50.0	4.4	**40**	104.4	21.1	**70**	158.0	37.8	**100**	212.0
−11.7	**11**	51.8	5.0	**41**	105.8	21.7	**71**	159.8	38.9	**102**	215.6
−11.1	**12**	53.6	5.6	**42**	107.6	22.2	**72**	161.6	40.0	**104**	219.2
−10.6	**13**	55.4	6.1	**43**	109.4	22.8	**73**	163.4	41.1	**106**	222.8
−10.0	**14**	57.2	6.7	**44**	111.2	23.3	**74**	165.2	42.2	**108**	226.4
− 9.4	**15**	59.0	7.2	**45**	113.0	23.9	**75**	167.0	43.3	**110**	230.0
− 8.9	**16**	60.8	7.8	**46**	114.8	24.4	**76**	168.8	44.4	**112**	233.6
− 8.3	**17**	62.6	8.3	**47**	116.6	25.0	**77**	170.6	45.6	**114**	237.2
− 7.8	**18**	64.4	8.9	**48**	118.4	25.6	**78**	172.4	46.7	**116**	240.8
− 7.2	**19**	66.2	9.4	**49**	120.2	26.1	**79**	174.2	47.8	**118**	244.4
− 6.7	**20**	68.0	10.0	**50**	122.0	26.7	**80**	176.0	48.9	**120**	248.0
− 6.1	**21**	69.8	10.6	**51**	123.8	27.2	**81**	177.8	50.0	**122**	251.6
− 5.6	**22**	71.6	11.1	**52**	125.6	27.8	**82**	179.6	51.1	**124**	255.2
− 5.0	**23**	73.4	11.7	**53**	127.4	28.3	**83**	181.4	52.2	**126**	258.8
− 4.4	**24**	75.2	12.2	**54**	129.2	28.9	**84**	183.2	53.3	**128**	262.4
− 3.9	**25**	77.0	12.8	**55**	131.0	29.4	**85**	185.0	54.4	**130**	266.0
− 3.3	**26**	78.8	13.3	**56**	132.8	30.0	**86**	186.8	55.6	**132**	269.6
− 2.8	**27**	80.6	13.9	**57**	134.6	30.6	**87**	188.6	56.7	**134**	273.2
− 2.2	**28**	82.4	14.4	**58**	136.4	31.1	**88**	190.4	57.8	**136**	276.8
− 1.7	**29**	84.2	15.0	**59**	138.2	31.7	**89**	192.2	58.9	**138**	280.4
− 1.1	**30**	86.0	15.6	**60**	140.0	32.2	**90**	194.0	60.0	**140**	284.0
− 0.6	**31**	87.8	16.1	**61**	141.8	32.8	**91**	195.8	61.1	**142**	287.6
0.0	**32**	89.6	16.7	**62**	143.6	33.3	**92**	197.6	62.2	**144**	291.2
+ 0.6	**33**	91.4	17.2	**63**	145.4	33.9	**93**	199.4	63.3	**146**	294.8
1.1	**34**	93.2	17.8	**64**	147.2	34.4	**94**	201.2	64.4	**148**	298.4
1.7	**35**	95.0	18.3	**65**	149.0	35.0	**95**	203.0			
2.2	**36**	96.8	18.9	**66**	150.8	35.6	**96**	204.8			
2.8	**37**	98.6	19.4	**67**	152.6	36.1	**97**	206.6			
3.3	**38**	100.4	20.0	**68**	154.4	36.7	**98**	208.4			
3.9	**39**	102.2	20.6	**69**	156.2	37.2	**99**	210.2			

APPENDIX II

THE METRIC SYSTEM

The metric system was developed by French scientists in 1790 and was specifically designed to be an easily used system of weights and measures to benefit science, industry, and commerce. The metric system is calculated entirely in powers of 10, so one need not work with the various mathematical bases used with the English system, such as 12 inches to a foot, 3 feet to a yard, and 5280 feet to a mile.

The system is based on the "meter" which is one ten-millionth of the distance from the Equator to the North Pole. It is possible to develop worldwide standards from this base of measurement. The metric system of weights is bassd on the gram, which is the weight of a specific quantity of water.

Soon after the system was developed scientists over the world adopted it and were able to deal with the mathematics of their experiments more easily. The data and particulars of their work could be understood by other scientists anywhere in the world. During the early 19th century many European nations adopted the new system for engineering and commerce. It was possible for these countries to trade manufactured goods with one another without worrying whether it would be possible to repair machinery from another country without also buying special wrenches and measuring tools. Countries could buy and sell machine tools and other sophisticated and precision machinery without troublesome modifications or alterations. It was much easier to teach the metric system, since meters can be changed to kilometers or centimeters with the movement of a decimal point, which is roughly like being able to convert yards to miles or inches by adding zeros and a decimal instead of multiplying by 1760 or dividing by 36.

With the exception of the United States, all the industrialized nations of the world have adopted the metric system. Even England and Canada are changing from their traditional systems of measure, and the metric system will be almost universal by 1980.

Although the metric system has not been officially legislated by the Congress, the metric system is becoming more prominent in this country. Most automobile mechanics own some metric wrenches to work on foreign cars or foreign components in American cars. Almoss all photographic equipment is built to metric standards. Chemicals and drugs are usually sold in metric quantities, and "calorie counters" are using a metric unit of thermal energy.

Because we are allied with countries who use the metric system, much of our military information is in metric terms. Military maps use meters and kilometers instead of miles, and many weapons are in metric sizes, such as 7.62 mm, 20 mm, 40 mm, 75 mm, and 155 mm. Interchange of military equipment has caused a mixture of metric and English measure equipment since World War I when the army adopted the French 75 mm field gun, and World War II when the Navy procured the Swedish 40 mm Bofors and the Swiss 20 mm Oerlikon heavy machine guns.

It is inevitable that the United States will officially adopt the metric system. Exactly when this happens and how rapidly the changeover will depend on economics, since the expense of retooling our industry and commerce to new measurements will be very great. The cost of conversion will be offset by increased earnings from selling machinery and products overseas. Another benefit is that scientists use the metric system, but their calculations now have to be translated into English measure to be used by industry. With adoption of the metric system ideas can go directly from the drawing board to the assembly line.

The Navy will be using the metric system more during the next few years. Although you will find it easier to solve problems using this system, at first you will find it difficult to visualize or to estimate quantities in unfamiliar units of measure.

Fortunately, many metric units can be related to equivalent units in the English system.

The meter which is the basic unit is approximately one-tenth longer than a yard.

The basic unit of volume, the liter, is approximately one quart. The gram is the weight of a cubic centimeter, or milliliter, of pure water and is the basic unit of weight. As a common weight though, the kilogram, or kilo, which equals the weight of a liter of water, weighs 2.2 pounds. The cubic centimeter (cc) is used where we would use the square inch, and where we measure by the fluid ounce, the metric system employs the milliliter (ml). For power measure the metric system uses the kilowatt (kW), which is approximately 1.3 horsepower.

In terms of distance, a land mile is eight-fifths of a kilometer and a nautical mile is 1.852 kilometers, or nearly 2 kilometers.

A basic metric expression of pressure is the kilogram per square centimeter, which is 14.2 psi, nearly 1 atmosphere of pressure.

When working on foreign machinery, you may notice that your half-inch, three-quarter inch, and one-inch wrenches will fit many of the bolts. These sizes correspond to 13 mm, 19 mm, and 26 mm respectively in the metric system, and are very popular because they are interchangeable. The 13/16-inch spark plug wrench, which is standard in this country, is intended to fit a 20 mm nut.

The basic quantities of the metric system are multiplied or divided by powers of 10 to give other workable values. We cannot easily measure machine parts in terms of a meter, so the millimeter, or one-thousandth of a meter is used. For very fine measure the micron, also called the micrometer, can be used. It is one-millionth part of a meter, or one-thousandth of a millimeter. For small weights the milligram, one-thousandth of a gram is used. All of these multiples are expressed with standard prefixes taken from Latin:

micro = 1/1,000,000
milli = 1/1,000
centi = 1/100
*deci = 1/10
*deca = 10
*hecto = 100
kilo = 1,000
*myria = 10,000
mega = 1,000,000

* Rarely used

Over the next few years the metric system will become more used by the Navy as well as by the civilian world. You will find it easy to work with once you have mastered the basic terms. It will be difficult to translate values from our present system to the metric system, but this operation will become unnecessary once the new measurements are totally adopted.

Tables of equivalent English measure and metric equivalents are essential when you work simultaneously with both systems. The table which follows shows the equivalent measures of the two systems. The columns on the left have the equivalent values which are accurate enough for most work, and on the right are the multiples used to convert the values with a high degree of accuracy.

METRIC CONVERSION

CONVERSION OF INCHES TO MILLIMETERS

Inches	Millimeters	Inches	Millimeters	Inches	Millimeters
0.001	0.025	0.290	7.37	0.660	16.76
0.002	0.051	0.300	7.62	0.670	17.02
0.003	0.076	0.310	7.87	0.680	17.27
0.004	0.102	0.320	8.13	0.690	17.53
0.005	0.127	0.330	8.38	0.700	17.78
0.006	0.152	0.340	8.64	0.710	18.03
0.007	0.178	0.350	8.89	0.720	18.29
0.008	0.203	0.360	9.14	0.730	18.54
0.009	0.229	0.370	9.40	0.740	18.80
0.010	0.254	0.380	9.65	0.750	19.05
0.020	0.508	0.390	9.91	0.760	19.30
0.030	0.762	0.400	10.16	0.770	19.56
0.040	1.016	0.410	10.41	0.780	19.81
0.050	1.270	0.420	10.67	0.790	20.07
0.060	1.524	0.430	10.92	0.800	20.32
0.070	1.778	0.440	11.18	0.810	20.57
0.080	2.032	0.450	11.43	0.820	20.83
0.090	2.286	0.460	11.68	0.830	21.08
0.100	2.540	0.470	11.94	0.840	21.34
0.110	2.794	0.480	12.19	0.850	21.59
0.120	3.048	0.490	12.45	0.860	21.84
0.130	3.302	0.500	12.70	0.870	22.10
0.140	3.56	0.510	12.95	0.880	22.35
0.150	3.81	0.520	13.21	0.890	22.61
0.160	4.06	0.530	13.46	0.900	22.86
0.170	4.32	0.540	13.72	0.910	23.11
0.180	4.57	0.550	13.97	0.920	23.37
0.190	4.83	0.560	14.22	0.930	23.62
0.200	5.08	0.570	14.48	0.940	23.88
0.210	5.33	0.580	14.73	0.950	24.13
0.220	5.59	0.590	14.99	0.960	24.38
0.230	5.84	0.600	15.24	0.970	24.64
0.240	6.10	0.610	15.49	0.980	24.89
0.250	6.35	0.620	15.75	0.990	25.15
0.260	6.60	0.630	16.00	1.000	25.40
0.270	6.86	0.640	16.26	....	....
0.280	7.11	0.650	16.51	....	....

CONVERSION OF MILLIMETERS TO INCHES

Millimeters	Inches	Millimeters	Inches	Millimeters	Inches
0.01	0.0004	0.35	0.0138	0.68	0.0268
0.02	0.0008	0.36	0.0142	0.69	0.0272
0.03	0.0012	0.37	0.0146	0.70	0.0276
0.04	0.0016	0.38	0.0150	0.71	0.0280
0.05	0.0020	0.39	0.0154	0.72	0.0283
0.06	0.0024	0.40	0.0157	0.73	0.0287
0.07	0.0028	0.41	0.0161	0.74	0.0291
0.08	0.0031	0.42	0.0165	0.75	0.0295
0.09	0.0035	0.43	0.0169	0.76	0.0299
0.10	0.0039	0.44	0.0173	0.77	0.0303
0.11	0.0043	0.45	0.0177	0.78	0.0307
0.12	0.0047	0.46	0.0181	0.79	0.0311
0.13	0.0051	0.47	0.0185	0.80	0.0315
0.14	0.0055	0.48	0.0189	0.81	0.0319
0.15	0.0059	0.49	0.0193	0.82	0.0323
0.16	0.0063	0.50	0.0197	0.83	0.0327
0.17	0.0067	0.51	0.0201	0.84	0.0331
0.18	0.0071	0.52	0.0205	0.85	0.0335
0.19	0.0075	0.53	0.0209	0.86	0.0339
0.20	0.0079	0.54	0.0213	0.87	0.0343
0.21	0.0083	0.55	0.0217	0.88	0.0346
0.22	0.0087	0.56	0.0220	0.89	0.0350
0.23	0.0091	0.57	0.0224	0.90	0.0354
0.24	0.0094	0.58	0.0228	0.91	0.0358
0.25	0.0098	0.59	0.0232	0.92	0.0362
0.26	0.0102	0.60	0.0236	0.93	0.0366
0.27	0.0106	0.61	0.0240	0.94	0.0370
0.28	0.0110	0.62	0.0244	0.95	0.0374
0.29	0.0114	0.63	0.0248	0.96	0.0378
0.30	0.0118	0.64	0.0252	0.97	0.0382
0.31	0.0122	0.65	0.0256	0.98	0.0386
0.32	0.0126	0.66	0.0260	0.99	0.0390
0.33	0.0130	0.67	0.0264	1.00	0.0394
0.34	0.0134	...	.....	...	.....

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OCCUPATIONAL STANDARDS

ELECTRICIAN'S MATE FIRST CLASS (EM1)

18 TEST EQUIPMENT

18442	Determine appropriate test equipment for tests and measurements	NET 10546-D

24 ELECTRICAL MAINTENANCE

24472	Isolate grounds, open circuits, and short circuits in ship's service and emergency generators and associated switch gear	1, 2, NET 10546-D
24473	Inspect and test-operate automatic starting equipment of emergency generators	NET 10546-D
24474	Conduct bench tests on electric governors	4
24475	Check logic or solid state electrohydraulic controllers	NET 10546-D
24476	Test, inspect, and direct repairs of automatic degaussing equipment	2
24477	Inspect ship's service and emergency switchboard equipment when power is secured	NET 10546-D
24478	Estimate extent of casualty to equipment under EM cognizance	4
24479	Identify and classify casulaties of motion-picture projection equipment as repairable at shipboard or tender level	NET 10546-D
24480	Remove, test, and replace defective components in automatic-degaussing control panels	2
24491	Determine type and value of acceptable substitute components	NET 10086-B

50 MAINTENANCE PLANNING AND QUALITY ASSURANCE

50934	Check electrical operating logs and maintenance records to determine if equipment is operating properly	3, NET 10546-D
50986	Review completed maintenance data collection sub-system (MDCS) F	5, NET 10054-D
50987	Prepare weekly schedules of preventive maintenance	NET 10054-D

54 LOGISTICS SUPPORT

54827	Post changes and additions to COSAL	NET 10056-C

CHIEF ELECTRICIAN'S MATE (EMC)

24 ELECTRICAL MAINTENANCE

24481	Test, inspect, and direct repairs of power and lighting equipment	2, 4, NET 10546-D
24482	Test, inspect, and direct repairs of static magnetic amplifier equipment	2
24483	Inspect, test, and direct repair of voltage and speed regulators associated with 400 Hertz systems	4, NET 10546-D
24484	Inspect, test, and direct repair of static inverters	4
24485	Inspect and direct maintenance and repair of casualty, emergency and special distribution electrical systems	4, 5, NET 10546-D

38 ADMINISTRATION

38949	Maintain files	NET 10858-E
38951	Direct operation and control of electrical distribution and interior communication systems and circuits	4
38952	Organize work within an electrical shop, establish work priorities and assign work	5, NET 10054-D
38953	Plan, organize, and direct work of personnel operating and maintaining electrical systems	5
38954	Supervise the qualifications of watch standers	NET 10057-C, PQS
38955	Prepare and maintain shipboard data collection sub-system (MDCS) submit reports	NET 10054-D

42 GENERAL WATCHSTANDING

42340	Interpret the duties of the engineering officer of the watch	EOSS

50 MAINTENANCE PLANNING AND QUALITY ASSURANCE

50984	Estimate time, materials, and labor required for repair of electrical systems and equipment	5
50988	Prepare quarterly schedules of preventive maintenance	NET 10054-D

54 LOGISTICS SUPPORT

54804	Enter changes to Ship Equipment Configuration Accounting System (SECAS) and submit report to SECAS Validation Field Office (VFC)	NET 10056-C NET 10057-C

98 ENVIRONMENTAL POLLUTION CONTROL

98243	Supervise compliance with environmental pollution control programs	NET 10115

ELECTRICIAN'S MATE 1 & C

NAVEDTRA 10547-D

Prepared by the Naval Education and Training Program Development
Center, Pensacola, Florida

Your NRCC contains a set of assignments and self-scoring answer sheets (packaged separately). The Rate Training Manual, Electrician's Mate 1 & C, NAVEDTRA 10547-D, is your textbook for the NRCC. If an errata sheet comes with the NRCC, make all indicated changes or corrections. Do not change or correct the textbook or assignments in any other way.

HOW TO COMPLETE THIS COURSE SUCCESSFULLY

Study the textbook pages given at the beginning of each assignment before trying to answer the items. Pay attention to tables and illustrations as they contain a lot of information. Making your own drawings can help you understand the subject matter. Also, read the learning objectives that precede the sets of items. The learning objectives and items are based on the subject matter or study material in the textbook. The objectives tell you what you should be able to do by studying assigned textual material and answering the items.

At this point you should be ready to answer the items in the assignment. Read each item carefully. Select the BEST ANSWER for each item, consulting your textbook when necessary. Be sure to select the BEST ANSWER from the subject matter in the textbook. You may discuss difficult points in the course with others. However, the answer you select must be your own. Use only the self-scoring answer sheet designated for your assignment. Follow the scoring directions given on the answer sheet itself and elsewhere in this course.

Your NRCC will be administered by your command or, in the case of small commands, by the Naval Education and Training Program Development Center. No matter who administers your course you can complete it successfully by earning grades that average 3.2 or higher. If you are on active duty, the average of your grades in all assignments must be at least 3.2. If you are NOT on active duty, the average of your grades in all assignments of each creditable unit must be at least 3.2. The unit breakdown of the course, if any, is shown later under Naval Reserve Retirement Credit.

WHEN YOUR COURSE IS ADMINISTERED BY LOCAL COMMAND

As soon as you have finished an assignment, submit the completed self-scoring answer sheet to the officer designated to administer it. He will check the accuracy of your score and discuss with you the items that you do not understand. You may wish to record your score on the assignment itself since the self-scoring answer sheet is not returned.

If you are completing this NRCC to become eligible to take the fleetwide advancement examination, follow a schedule that will enable you to complete all assignments in time. Your schedule should call for the completion of at least one assignment per month.

Although you complete the course successfully, the Naval Education and Training Program Development Center will not issue you a letter of satisfactory completion. Your command will make a note in your service record, giving you credit for your work.

WHEN YOUR COURSE IS ADMINISTERED BY THE NAVAL EDUCATION AND TRAINING PROGRAM DEVELOPMENT CENTER

After finishing an assignment, go on to the next. Retain each completed self-scoring answer sheet until you finish all the assignments in a unit (or in the course if it is not divided into units). Using the envelopes provided, mail your self-scored answer sheets to the Naval Education and Training Program Development Center where the scores will be verified and recorded. Make sure all blanks at the top of each answer sheet are filled in. Unless you furnish all the information required, it will be impossible to give you credit for your work. You may wish to record your scores on the assignments since the self-scoring answer sheets are not returned.

The Naval Education and Training Program Development Center will issue a letter of satisfactory completion to certify successful completion of the course (or a creditable unit of the course). To receive a course-completion letter, follow the directions given on the course-completion form in the back of this NRCC.

You may keep the textbook and assignments for this course. Return them only in the event you disenroll from the course or otherwise fail to complete the course. Directions for returning the textbook and assignments are given on the book-return form in the back of this NRCC.

PREPARING FOR YOUR ADVANCEMENT EXAMINATION

Your examination for advancement is based on the Manual of Navy Enlisted Manpower and Personnel Classification and Occupational Standards (NAVPERS 18068-D). The sources of questions in this examination are given in the Bibliography for Advancement Study (NAVEDTRA 10052). Since your NRCC and textbook are among the sources listed in this bibliography, be sure to study both in preparing to take your advancement examination. The standards for your rating may have changed since your course and textbook were printed, so refer to the latest editions of NAVPERS 18068-D and NAVEDTRA 10052.

NAVAL RESERVE RETIREMENT CREDIT

This course is evaluated at 12 Naval Reserve retirement points. These points are creditable to personnel eligible to receive them under current directives governing retirement of Naval Reserve Personnel. Points will be credited upon satisfactory completion of the entire course. Naval Reserve retirement credit will not be given if the student has previously received credit for any Electrician's Mate 1&C, NRCC or ECC.

COURSE OBJECTIVE

When you complete this course, you will be able to supervise an electrical gang to ensure that safe practices are a way of life aboard ship. You will be able to point out to your junior petty officers the operating principles of voltage regulators, transistorized control devices, automatic degaussing systems, gyrocompasses, no break power supplies, electrohydraulic load-sensing speed governors, and visual landing aids. In addition, you will be able to help them troubleshoot and maintain these systems using the appropriate technical manual as a guide. You will also be able to brief your men on the details of maintenance administration as well as to guide them through the administrative details of a yard overhaul.

While working on this nonresident career course, you may refer freely to the text. You may seek advice and instruction from others on problems arising in the course, but the solutions submitted must be the result of your own work and decisions. You are prohibited from referring to or copying the solutions of others, or giving completed solutions to anyone else taking the same course.

Naval nonresident career courses may include a variety of items -- multiple-choice, true-false, matching, etc. The items are not grouped by type; regardless of type, they are presented in the same general sequence as the textbook material upon which they are based. This presentation is designed to preserve continuity of thought, permitting step-by-step development of ideas. Some courses use many types of items, others only a few. The student can readily identify the type of each item (and the action required of him) through inspection of the samples given below.

MULTIPLE-CHOICE ITEMS

Each item contains several alternatives, one of which provides the best answer to the item. Select the best alternative and erase the appropriate box on the answer sheet.

SAMPLE

s-1. The first person to be appointed Secretary of Defense under the National Security Act of 1947 was

1. George Marshall
2. James Forrestal
3. Chester Nimitz
4. William Halsey

The erasure of a correct answer is indicated in this way on the answer sheet:

	1 T	2 F	3	4	
s-1	■	C	■	■	

TRUE-FALSE ITEMS

Determine if the statement is true or false. If any part of the statement is false the statement is to be considered false. Erase the appropriate box on the answer sheet as indicated below.

SAMPLE

s-2. Any naval officer is authorized to correspond officially with a bureau of the Navy Department without his commanding officer's endorsement.

The erasure of a correct answer is also indicated in this way on the answer sheet:

	1 T	2 F	3	4	
s-2	■	CC	■	■	

MATCHING ITEMS

Each set of items consists of two columns, each listing words, phrases or sentences. The task is to select the item in column B which is the best match for the item in column A that is being considered. Specific instructions are given with each set of items. Select the numbers identifying the answers and erase the appropriate boxes on the answer sheet.

SAMPLE

In items s-3 through s-6, match the name of the shipboard officer in column A by selecting from column B the name of the department in which the officer functions.

A. Officers	B. Departments
s-3. Damage Control Assistant	1. Operations Department
s-4. CIC Officer	2. Engineering Department
s-5. Assistant for Disbursing	3. Supply Department
s-6. Communications Officer	

The erasure of a correct answer is indicated in this way on the answer sheet:

	1 T	2 F	3	4	
s-3	■	C	■	■	
s-4	C	■	■	■	
s-5	■	■	C	■	
s-6	C	■	■	■	

How To Score Your Immediate Knowledge of Results (IKOR) Answer Sheets

	1 T	2 F	3	4	
1	■	C	6	■	1
2	C	9	■	9	2
3	■	■	C	■	
4	CC	12	■	■	1

Total the number of incorrect erasures (those that show page numbers) for each item and place in the blank space at the end of each item.

Sample only

Number of boxes erased incorrectly	0-2	3-7	8-
Your score	4.0	[✓ 3.9]	3.8

Now TOTAL the column(s) of incorrect erasures and find your score in the Table at the bottom of EACH answer sheet.

NOTICE: If, on erasing, a page number appears, review text (starting on that page) and erase again until "C", "CC", or "CCC" appears. For courses administered by the Center, the maximum number of points (or incorrect erasures) will be deducted from each item which does NOT have a "C", "CC", or "CCC" uncovered (i.e., 3 pts. for four choice items, 2 pts. for three choice items, and 1 pt. for T/F items).

Assignment 1

Career Program, Safety, and Voltage and Frequency Regulation

Textbook Assignment: Pages 1 through 30

In this course you will demonstrate that learning has taken place by correctly answering teaching items. The mere physical act of indicating a choice on an answer sheet is not in itself important; it is the mental achievement, in whatever form it may take, prior to the physical act that is important and toward which nonresident career course learning objectives are directed. The selection of the correct choice for a nonresident career course teaching item indicates that you have fulfilled, at least in part, the stated objective(s).

The accomplishment of certain objectives, for example, a physical act such as drafting a memo, cannot readily be determined by means of objective type nonresident career course items; however, you can demonstrate by means of answers to teaching items that you have acquired the requisite knowledge to perform the physical act. The accomplishment of certain other learning objectives, for example, the mental acts of comparing, recognizing, evaluating, choosing, selecting, etc., may be readily demonstrated in a nonresident career course by indicating the correct answers to teaching items.

The comprehensive objective for this course has already been given. It states the purpose of the course in terms of what you will be able to do as you complete the course.

The detailed objectives in each assignment state what you should accomplish as you progress through the course. They may appear singly or in clusters of closely related objectives, as appropriate; they are followed by items which will enable you to indicate your accomplishment.

All objectives in this course are learning objectives and items are teaching items. They point out important things, they assist in learning, and they should enable you to do a better job for the Navy.

This nonresident career course is only one part of the total Navy teaching program; by its very nature it can take you only part of the way to a learning goal. Practical experience, schools, selected reading, and the desire to accomplish are also necessary to round out a fully meaningful learning program.

Learning Objective: Recognize the benefits and responsibilities acquired through advancement. Texttook pages 1 and 2.

1-1. Advancements in rating are profitable to both the personnel being advanced and to the Navy. One of the most lasting personal benefits you receive from advancement is the

1. more challenging assignments you get because you can shoulder increased responsibility
2. higher standard of living you can maintain because of increased pay
3. greater prestige you acquire when given more authority
4. satisfaction you derive in developing knowledge

1-2. Why should a petty officer strive constantly to improve his use of grammar and technical terms pertaining to his rating?

1. To increase his ability to communicate with others
2. To avoid criticism by trainees having higher formal education
3. To vitalize his technique of instruction
4. To impress trainees with his superior command of language

1-3. An EM1 or EMC must keep himself informed of all changes and new developments that affect his rating or work.

Learning Objective: Point out sources of information and requirements for advancement. Textbook pages 3 through 9.

1-4. In addition to his examination score, other factors influencing the advancement of an EM2 qualified for EM1 include all the following except
   1. his length of time in service
   2. his performance marks
   3. the amount of sea duty he has served
   4. the number of vacancies in the EM rating

In items 1-5 and 1-6 select the publication from column B that is a source of the information in column A.

A. Information	B. Publications
1-5. Minimal practical factors applicable to each rate within the EM rating	1. Manual of Navy Enlisted Manpower and Personnel Classification and Occupational Standards
1-6. Latest edition of a given Rate Training Manual	2. Training Publications for Advancement
	3. Bibliography for Advancement Study
	4. Naval Training Bulletin

1-7. Which of the following actions should an EM take when he is transferred from one activity to another?
   1. Request a statement concerning his qualifications from the activity he is leaving
   2. Secure his NAVEDTRA Form 1414/1 and take it to his new commanding officer
   3. Inform his new division chief that he has completed his practical factors
   4. Insure that his NAVEDTRA Form 1414/1 is up to date and is in his service record

1-8. Which of the courses listed for your rating in NAVEDTRA 10052 must you complete before you are eligible to take the advancement examinations?
   1. All courses listed for the Engineering and Hull group
   2. All courses listed for the next higher rate
   3. Asterisked courses listed for the next higher rate
   4. Unmarked courses listed for the next higher rate

1-9. The completion requirement for a mandatory rate training course marked with an asterisk (*) in NAVEDTRA 10052 may be satisfied by
   1. passing the nonresident career course
   2. successful completion of the appropriate school
   3. both 1 and 2
   4. successfully demonstrating your skills

1-10. Appropriate officer texts and their companion correspondence courses are useful as sources of information to personnel preparing for advancement to EM1 or EMC.

Learning Objective: Recognize principles of electrical safety and effects of electric shock on the human body. Textbook pages 10 through 12.

1-11. The extent of body damage caused by electrical shock depends on which of the following?
   1. Size of the body
   2. Value of voltage touched by the body
   3. Amount and duration of current flow through the body
   4. Whether the current is a.c. or d.c.

1-12. Which value of 60-hertz current flowing through the body from hand to foot for 2 seconds is fatal?
   1. 0.0001 amp
   2. 0.001 amp
   3. 0.010 amp
   4. 0.100 amp

1-13. The human body will not receive an electric shock unless the body forms part of a closed circuit and a difference in potential exists.

1-14. When the human body is shocked by more than 200 ma of 60-hertz current, the chest muscles contract to clamp the heart and stop it for as long as the shock lasts.

1-15. For which purpose are signs posted in work areas?
1. To eliniate danger
2. To eliminate hazards
3. Both 1 and 2 are correct
4. To alert working personnel to possible injury

1-16. By what means is the operator of a portable metal-case electric tool protected from electric shock?
1. By grounding conductor and insulation on the tool and its cord
2. By grounding conductor and insulation on the distribution system
3. By grounding conductor, insulation on the distribution system, and insulation on the tool and its cord
4. By insulation on the distribution system and insulation on the tool and its cord

1-17. Which of the following resistance values for the ground connections between the metal case of a portable electric drill and the steel structure of a ship should protect the drill operator from electric shock?
1. 0.9 ohms or less
2. 2.0 ohms to 5 ohms
3. 5 ohms or more
4. All of the above

1-18. When instructing personnel in the nonelectrical ratings on matters regarding electrical safety, which of the following statements should you emphasize?
1. Voltages as low as 30 volts are hazardous
2. Danger from electric shock is greater ashore than aboard ship
3. Only painful shocks received from electrical equipment should be reported
4. All personal portable radios and record players are safe to use aboard ship

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Learning Objective: Recognize safe and unsafe working conditions or practices associated with switchboards, test equipment, hand tools, batteries, shore power, and cleaning agents. Textbook pages 12 through 21.

1-19. Operators of power-driven machines can help avoid accidents by making it a practice to
1. remove chips with compressed air
2. wear gloves and a long-sleeved shirt
3. have sufficient light to work by
4. remove machine guards before starting

1-20. When, if ever, should gasoline be used for cleaning aluminum?
1. When liberal ventilation is provided
2. When use of a chlorinated solvent would damage the aluminum
3. When inhibited methyl chloroform is unavailable
4. Never

1-21. Which solvent are you permitted to use for cleaning electrical insulation only after having proved that the solvent will not damage the insulation?
1. Gasoline or benzine
2. Methyl chloroform or dry cleaning solvent, type II
3. Trichloroethylene
4. Inhibited methyl chloroform

1-22. Which step can maintenance personnel take safely when cleaning equipment with inhibited methyl chloroform?
1. Wear a chemical cartridge air respirator
2. Inhale its vapor directly
3. Apply it in the presence of an open flame
4. Use a vaporproof or watertight portable light

1-23. Which practice for minimizing fire hazards applies when a safety type dry cleaning solvent is being sprayed?
1. Cleaning the sprayer nozzles
2. Grounding vaporproof lights
3. Grounding watertight portable lights
4. Grounding the sprayer nozzles

1-24. The practice of spraying a solvent near an open flame or on hot equipment is safe provided the solvent is a safety type such as type II dry cleaning solvent.

1-25. Give one reason for maintaining an adequate and constant supply of fresh air in a battery locker.
1. To help evaporate any electrolyte that overflows from batteries on the line
2. To keep the temperature of the locker from dropping below 95° F
3. To prevent the formation of an explosive mixture of air and hydrogen given off by batteries being charged
4. To permit the use of a battery charging rate that will force battery temperatures to rise above 125° F

1-26. The temperature of a battery locker should be maintained at
1. 95° F or lower
2. 100° F or lower
3. 95° F or higher
4. 100° F or higher

1-27. Under normal conditions, what should you do if battery locker ventilation is interrupted while the batteries are being charged?
1. Stop battery charging until ventilation is restored
2. Reduce the charging rate of all batteries
3. Reduce the charging rate of half of the batteries
4. Determine the cause of ventilation loss

1-28. When charging batteries what should you do before repairing a connection to a battery on the line?
1. Lower the charging rate
2. Turn off the charging current
3. Discharge the battery
4. Reduce the charging voltage

1-29. When removing a battery which has one grounded terminal, you disconnect the ungrounded terminal first.

1-30. What is the proper way to mix electrolyte?
1. Pour acid slowly into the water
2. Pour water slowly into the acid
3. Pour acid rapidly into the water
4. Pour water rapidly into the acid

1-31. Before closing any switch, be sure that
1. the circuit is ready in all respects to be energized
2. any men working on the circuit are notified
3. only one hand is used if possible
4. all of the above are done

1-32. What is the procedure for placing warning tags on switches when more than one repair party is working on a circuit that can be energized by closing the switches?
1. Each party tags the switch nearest his work site
2. Each party tags each switch in the circuit
3. Party to begin work first tags each switch in the circuit
4. Party to begin work first tags the switch nearest his work site

1-33. Before starting repair work on a deenergized switchboard, you should make sure that the metering and control circuits are deenergized.

1-34. Before any work is done on an energized switchboard, who must give approval to do the work?
1. Electrical officer
2. Damage control assistant
3. Engineer officer
4. Commanding officer

1-35. Which of the following materials is suitable for covering grounded metal to keep a worker from coming in contact with the metal?
1. Dry canvas that has holes in it
2. Dry phenolic material that has a conductor imbedded in it
3. Dry insulating material that contains no holes or conductors
4. Damp plywood

1-36. In most installations, potential transformer primaries are deenergized by
1. opening circuit breakers
2. opening knife switches
3. pulling fuses
4. opening selector switches

1-37. Assume that you are connecting a ship's switchboard to a source of electrical power ashore. You conduct a check which shows that the phase sequence is incorrect. What should you do to correct the phase sequence?
1. Deenergize the cable, then reenergize the cable and disconnect the phase sequence meter
2. Deenergize the cable, connect the phase sequence meter, and reenergize the cable
3. Deenergize the cable, check the phase sequence meter connections, and if they are incorrect, interchange any two of the shore power cable conductors
4. Deenergize the cable, check the phase sequence meter connections, and interchange any two of the shore power cable conductors if the phase sequence meter connections are correct

1-38. Before disconnecting a shore power cable after having shifted the electrical load to the ship's generators, you should first
1. test the male prongs of the plug-in type cable
2. ensure that the ship's shore power circuit breaker at the switchboard is off and tagged
3. ensure that the cable is deenergized
4. test the terminals at the ship's shore terminal box

1-39. To prevent damage to electric meters, you should protect them against the effects of
1. weak magnetic fields
2. low currents
3. both 1 and 2
4. mechanical shock

1-40. Instruments being used on a vibrating surface should be placed on thick pads of felt or cloth to protect them from damage.

1-41. What should you do to ensure that metal-case test instruments are safe to use?
1. Energize the instruments
2. Ground the metal cases
3. Insulate each metal case from ground
4. Connect all metal cases to a common lead

1-42. You should work barehanded when testing voltages that are likely to exceed 300 volts.

Learning Objective: Identify obligations of the senior electrician for supervising all facets of electrical safety aboard ship. Textbook pages 10 through 22.

1-43. If safety precautions have not been issued or are incomplete, who issues the safety precautions that are deemed necessary?
1. Division officer
2. Engineer officer
3. Commanding officer
4. Type command

1-44. As the leading EM aboard a ship, you have a responsibility to instruct the enlisted men of E division and other divisions in matters regarding electrical safety.

1-45. The commanding officer delegates his authority for enforcing safety to
1. leading petty officers
2. division officers
3. engineering officers
4. all of the above

1-46. What is the greatest cause of electric shock aboard ship?
1. Equipment failure
2. Poor equipment
3. Equipment design
4. Human error

1-47. During a visit to the machine shop an Electrician's Mate Second Class observes a man working without goggles at a drill press. What should the electrician do?
1. Stop the work
2. Notify the petty officer in charge of the shop
3. Provide the man with goggles
4. Put the man on report

1-48. When shore power is being rigged by two working parties, who is responsible for ensuring the ship's rigging procedures are followed?
1. Shore supervisor
2. Ship's supervisor
3. Ship's electrical officer
4. Ship's Officer of the Deck

It is the responsibility of the Officer of the Deck to verify that the Chief Engineer and Communication Officer have been notified that a man is going aloft. He also notifies the Officer of the Deck of adjoining ships, when ships are alongside. The leading or senior petty officer should ensure that the man going aloft, his assistant who remains on deck, and the Ship's Boatswain's Mate know the applicable safety precautions.

1-49. Sometimes, men working aloft are required to work with tools without preventer lines.

1-50. Who grants permission for a man to work aloft?
1. Commanding officer
2. Communication officer
3. Chief Engineer
4. Officer of the Deck

1-51. Who is the source of supply of High Voltage Warning Sign NavSea No. RE 10B 608B?
1. Supply Officer, Mechanicsburg, Pennsylvania
2. Communication Officer
3. Commander, Philadelphia Naval Shipyard
4. Ship's Supply Officer

1-52. What is the best means at your disposal for eliminating jury-rigged electrical equipment from your ship?
1. Publish facts in the ship's plan of the day about the hazards of jury rigs
2. Emphasize the hazards of jury rigs each time an opportunity arises
3. Post safety reminders throughout the ship
4. Conduct periodic safety inspections yourself

Learning Objective: Recognize standard electrical characteristics of shipboard a.c. power systems. Textbook pages 23 and 24.

1-53. When expressed in percentage, which of the following ratios defines the harmonic content of an a.c. power system?
1. Effective value of voltage variations divided by the equipment voltage rating
2. Equipment voltage rating divided by the effective value of voltage variations
3. Effective value of voltage variations that remain after elimination of the fundamental voltage divided by the equipment voltage rating
4. Equipment voltage rating multiplied by the square root of 2 and divided by the effective value of voltage variations remaining after elimination of the fundamental voltage

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In items 1-54 through 1-56 select from column B the factor which, when divided by the equipment voltage rating, defines the electrical characteristic in column A.

	A. Electrical Characteristics		B. Factors
1-54.	Modulation amplitude	1.	Effective value of voltage variations
1-55.	Steady state tolerance band	2.	Highest phase voltage minus lowest phase voltage
1-56.	Voltage unbalance between phases	3.	Periodic variation in voltage caused by regulators, intermittent loads, or other random disturbances
		4.	Maximum average voltage variation caused by drift, environment, and load changes (excluding transient load changes)

Learning Objective: Recognize the characteristics of type I and type II a.c. power systems. Textbook page 24 and Table 3-1.

1-57. Which electrical characteristic is expressed as ±18% in table 3-1 of the textbook?
1. Difference between the highest phase voltage and the lowest phase voltage
2. Maximum difference between the voltage wave and the harmonic content
3. Changing conditions of frequency that goes beyond and returns to the steady state tolerance band within the recovery time
4. Changing conditions of voltage that goes beyond and returns to the steady state tolerance band within the recovery time

1-58. Which electrical characteristic of type II a.c. power systems is expressed in textbook table 3-1 as 0.25 second at 400 hertz and 0.75 second at 60 hertz?
1. After a voltage change is initiated, the time it takes the voltage to recover and remain within the steady state tolerance band
2. After a frequency change is initiated, the time it takes the frequency to recover and remain within the steady state frequency band
3. Duration of voltage unbalance between phases caused by transient load changes
4. Duration of voltage unbalance between phases caused by random disturbances

1-59. What are the respective maximum and minimum line to line 3-phase voltages permitted for a 440-volt, type II, a.c. power system?
1. 444 V and 436 V
2. 448 V and 432 V
3. 444 V and 440 V
4. 440 V and 436 V

1-60. The main difference between type I and type II power systems is that type II requires
1. better voltage control at the load
2. isolation of the load from the power system
3. less frequency regulation
4. generator voltage control rather than load voltage control

1-61. The maximum difference between the voltage wave and harmonic content of a 440-volt type III a.c. power system is approximately
1. 26 V
2. 31 V
3. 37 V
4. 40 V

Learning Objective: Point out operating principles of the direct-acting type voltage regulator and procedures for operating ship's service installations using this type of regulator. Textbook pages 25 through 30.

1-62. The silver buttons in a silverstat type voltage regulator are connected to taps on the
1. regulator coil
2. voltage adjusting rheostat
3. regulating resistance plates
4. range-setting resistors

1-63. The range covered by each voltage adjusting rheostat of the regulator can be set so the midposition of the rheostat is the normal operating position to obtain rated generator voltage. The range is set by means of a
1. damping transformer
2. resistor connected in series with the regulator coil
3. resistance plate connected in series with the rheostat
4. resistance plate connected in parallel with the rheostat

1-64. Where is the primary of the damping transformer connected in a regulator that controls a large a.c. generator?
1. Across the output of the exciter
2. In series with the voltage adjusting rheostat
3. In series with the regulator coil
4. Across the output of the crosscurrent compensator

1-65. When switching a direct acting voltage regulator system from manual to automatic control it is necessary to leave the control switch in the TEST position momentarily to allow the

1. exciter field current to stabilize
2. generator field current to stabilize
3. damping transformer transient current to die down
4. silver buttons to readjust

1-66. How does a direct acting voltage regulator respond to a decrease in generator load?

1. The regulator armature is pulled toward the regulator coil, more silver buttons are pushed together, and the regulating resistance increases
2. The regulator armature is pulled toward the regulator coil, more silver buttons are spread apart, and the regulating resistance increases
3. The regulator armature is pulled away from the regulator coil, more silver buttons are pushed together, and the regulating resistance decreases
4. The regulator armature is pulled away from the regulator coil, more silver buttons are spread apart, and the regulating resistance decreases

1-67. How will the moving arm of a direct acting regulator behave if the damping transformer connections are reversed?

1. It will swing continuously from one end of its travel to the other
2. It will move very sluggishly in response to a generator voltage change
3. It will be pulled toward the regulator coil and remain in that position
4. It will be pulled away from the regulator coil and remain in that position

Assignment 2

Voltage and Frequency Regulation; Transistorized Control Devices; and Automatic Degaussing

Textbook Assignment: pages 30 through 85

Learning Objective: Identify operating principles of the rotary amplifier (amplidyne) type of voltage regulator and procedures for operating ship's service installations using this type of regulator. Textbook pages 30 through 39.

2-1. When the voltage regulator transfer switch for two generators, A and B is in the GEN B position, how are the voltages of the generators controlled?
   1. Both generators are controlled by generator B's regulator
   2. Only generator B is regulated, since generator A is out of the circuit
   3. Generator A is controlled by its own regulator, and generator B is controlled by the standby regulator
   4. Generator A is controlled by the standby regulator and generator B is controlled by its own regulator

2-2. When the number of saturated reactor coil turns in the voltage adjusting unit is decreased, the inductance of the saturated reactor
   1. increases, and the voltage held by the regulator is raised
   2. increases, and the voltage held by the regulator is lowered
   3. decreases, and the voltage held by the regulator is raised
   4. decreases, and the voltage held by the regulator is lowered

2-3. The unit that provides the regulator with a signal proportional to the a.c. generator voltage is the
   1. pilot alternator
   2. potential unit
   3. amplidyne
   4. stabilizer

2-4. The stabilizer functions to prevent hunting in the voltage regulator circuit by producing a voltage that
   1. aids any change in amplidyne control field current
   2. opposes any change in amplidyne control field current
   3. increases the inductance of the saturated reactor
   4. decreases the inductance of the saturated reactor

2-5. When generator voltage is near normal in the automatic control circuit of textbook figure 3-6, buck circuit current from F2 to F1 in the amplidyne control field is
   1. negligible
   2. maximum to overcome the boost circuit current
   3. minimum to enable the boost circuit current to keep the amplidyne control field steady
   4. nearly equal to the boost circuit current

2-6. How does the automatic control circuit act to oppose an increase in a.c. generator voltage?
   1. The pilot alternator voltage increases, causing an increase in amplidyne control field current
   2. The pilot alternator voltage decreases, causing a decrease in amplidyne control field current
   3. The saturated reactor current increases, causing an increase in amplidyne control field current
   4. The saturated reactor current decreases, causing a decrease in amplidyne control field current

2-7. How does a decrease in generator frequency affect the reactances of the saturated reactor and the frequency compensation circuit?
1. The reactance of the saturated reactor increases, and the frequency compensation network behaves like an inductance
2. The reactance of the saturated reactor increases, and the frequency compensation network behaves like a capacitance
3. The reactance of the saturated reactor decreases, and the frequency compensation network behaves like an inductance
4. The reactance of the saturated reactor decreases, and the frequency compensation network behaves like a capacitance

2-8. At unity power factor, the compensating voltage across the compensating potentiometer rheostat is in phase with the
1. voltage across the teaser leg of the T-connected potential transformer secondary
2. resultant output voltage of the 3-phase response network
3. phase B line-to-neutral voltage
4. voltage across the resistor-inductor series circuit in the 3-phase response network

2-9. When two generators are being placed in parallel operation in a rotary voltage regulator system, load distribution and power factor are adjusted by means of the
1. manual control handwheels and prime mover governors
2. manual control handwheels and voltage adjusting unit
3. voltage adjusting unit and prime mover governors
4. voltage adjusting unit and saturated reactor tap switch

Learning Objective: Recognize operating principles of the static excitation voltage regulator system and procedures for operating ship's service installations using this system. Textbook pages 39 through 49.

2-10. Switches S1 and S2 contain a large number of series-connected contacts for the purpose of
1. eliminating arcing when turned to the OFF position
2. minimizing arcing effects when power is removed
3. providing multiple circuit path connections
4. preventing the contacts from becoming hot

2-11. The output of the static exciter is controlled by the current through the
1. transformer primaries
2. transformer secondaries
3. transformer control windings
4. output rectifier CR1

2-12. The initial field current for starting the a.c. generator is provided by a field-flashing circuit from
1. the static exciter
2. the output rectifiers
3. a 50 kW, d.c. generator
4. all of the above

2-13. The automatic voltage regulator maintains the generator's output voltage by regulating the direct current through the static exciter's
1. control winding
2. primary winding
3. linear inductor
4. secondary winding

In items 2-14 through 2-19 refer to textbook figures 3-14 through 3-16.

2-14. The reactance value of L6 in the voltage regulator is dependent on the
1. average of the line voltages
2. output of CR6
3. value of the secondary of T5
4. output of CW1

2-15. The amount of voltage across filter capacitor C1 is
1. proportional to the voltage drop across R8
2. equal to the output of T6
3. proportional to the line voltage average
4. equal to the amount of ripple when the line voltages are unequal

2-16. What condition will cause current to flow in the primary winding of CW4 in such a manner that exciter voltage will increase?
1. V_E equal to V_R and V_L
2. V_E greater than V_R
3. V_R greater than V_L
4. V_E greater than V_L

2-17. The amount of flux in the magnetic amplifier cores is controlled by the
1. output of transformer T5
2. output of the comparison circuit
3. amount of gated a.c. in CW5
4. setting of voltage adjusting rheostat R6

2-18. When does maximum current flow in the load winding?
1. When the flux is zero
2. When the flux is greater than zero but the core is not saturated
3. When the core has been saturated by the control winding
4. When the core has been saturated by the load winding

2-19. Each magnetic amplifier is operated in the center portion of its magnetic core saturation curve by adjusting
1. L7 and R13
2. R11 and R12
3. L6 and L7
4. R14 and R15

2-20. You are checking the reactive droop compensation circuits of a.c. generators A and B prior to placing them in parallel operation. Generator A is satisfactory. When you add a reactive lagging load to generator B, the terminal voltage decreases. What should you do next?
1. Connect the two generators in parallel
2. Secure the generator and reverse the secondary leads of T4
3. Secure the generators and reverse the secondary leads of T6
4. Equalize the voltage decrease to that of generator A by adjusting R8

Learning Objective: Identify parts of the static exciter and regulator by their functions within their associated circuits. Textbook pages 50 through 57.

2-21. How are the current transformers of the exciter connected?
1. In parallel with the generator field and the armature
2. In parallel with the generator terminals and the load
3. In series with the generator field and the armature
4. In series with the generator terminals and the load

2-22. The d.c. excitation is the output of the field rectifier bridge. What furnishes the a.c. power to the rectifier bridge?
1. Linear reactors
2. Saturable transformers
3. Current transformers
4. All of the above

2-23. Under no-load conditions, which of the following determines the output of the field rectifier bridge?
1. Linear reactors and saturable transformers
2. Saturable transformers and current transformers
3. Current transformers and saturable transformers
4. Paralleling current transformers

2-24. The output of the current transformers is proportional to the
1. field rectifier current
2. saturable transformer voltage
3. load
4. synchronous reactance

2-25. How does the voltage regulator control mismatch between exciter and generator?
1. It regulates the voltage to the current transformer
2. It regulates the control current winding of the saturable transformer
3. It regulates the voltage to the field flashing system
4. It regulates the control current winding of the linear reactor

2-26. Which of the following are functions of the voltage regulator?
1. Sense terminal voltage
2. Rectify
3. Amplify and compare
4. All of the above

2-27. In the sensing circuit, shown in figure 4-2 of the text, what is the purpose of R6, R14, and R16?
1. To serve as a voltage divider
2. To provide power to choke L2
3. To compensate for capacitor C1
4. Each of the above

2-28. The generator voltage is sensed by
1. diodes CR1, CR2, CR3, CR4, CR5, and CR6
2. transformer T2
3. resistor R14
4. choke L2

2-29. One purpose of the amplifier and reference circuit (fig. 4-3 of the text) is to compare the error signal or voltage with a reference voltage. What is the source of the reference voltage?
1. Transistor Q3
2. Zener diode VR2
3. Transistor Q4
4. Magnetic amplifier L1

2-30. In figures 4-2 and 4-3 of the text, what parts of the sensing circuit and the amplifier and reference circuits are common?
1. Voltage divider and T2
2. L2 and voltage divider
3. L1 and T2
4. Q4 and VR2

2-31. In figure 4-5 of the text what is the source of reference voltage for Q3 and where is it applied?
1. VR2, emitter of Q3
2. VR1, base of Q3
3. VR2, base of Q3
4. VR1, emitter of Q3

2-32. If there is a decrease in generator voltage to T2, what is the end result at L1?
1. Output voltage remains the same
2. Output voltage decreases
3. Output voltage increases
4. Input voltage decreases

2-33. In the rectifier circuit, what parts prevent snap-on action of magnetic amplifier L1?
1. SCR thyristor CR10 and CR11
2. Diodes CR7 and CR9
3. Resistor R24 and capacitor C7
4. All of the above

2-34. Manual control of the generator provides a method to counteract generator voltage variations caused by
1. increase in load
2. variation in temperature
3. decrease in load
4. each of the above

2-35. Diodes CR58, CR59, CR60, CR61, CR62, and CR63 form a full-wave bridge rectifier. What is the source of a.c. for this rectifier?
1. L1
2. A.c. generator
3. Permanent magnet alternator (PMA)
4. Transformer T4

Learning Objective: Point out operating principles and maintenance requirements of an SPR-400 voltage regulator. Textbook pages 61 through 63.

2-36. The purpose of the SPR-400 line voltage regulator is to ensure precision control of variations in
1. line
2. load
3. power factor
4. all the above

2-37. What effect does a decrease of direct current in the control winding have on the operation of the autotransformer?
1. The voltage in the opposing winding decreases and the output decreases
2. The voltage in the opposing winding decreases and the output increases
3. The voltage in the opposing winding increases and the output decreases
4. The voltage in the opposing winding increases and the output increases

2-38. The pulse circuit Q1 responds to an error signal and regulates the output voltage.

2-39. The purpose of potentiometer R21 in figure 4-6 of the textbook is to compensate for the
1. resistance in the cables from regulator to load
2. internal resistance of the regulator
3. resistance of the regulator load
4. resistance of the input voltage

2-40. Frequent inspections for dust, dirt, and moisture must be made in an SPR-400 line voltage regulator.

Learning Objective: Recognize the purpose and operation of a synchronizing monitor. Textbook pages 63 through 73.

- When answering items 2-21 and 2-22, refer to figures 4-13 and 4-14 in your textbook.

2-41. The K1 relay is energized for which of the following examples of phase angle (θ), voltage difference (ΔV), and frequency difference (ΔF)?
1. θ = -45°; ΔV = 1%; ΔF = 0.1 hz
2. θ = -22°; ΔV = 3%; ΔF = 0.1 hz
3. θ = 0°; ΔV = 5%; ΔF = 0.5 hz
4. θ = + 5°; ΔV = 5%; ΔF = 2.0 hz

2-42. Assume that the synchronizing monitor is connected to a circuit consisting of two generators and that the K1 relay is energized. How does this affect the parallel operation of the generators?
1. The generators are automatically paralleled
2. The generators are not automatically paralleled but may be manually paralleled
3. The generators may not be paralleled while the K1 relay is energized but are automatically paralleled when it is deenergized
4. The generators may not be paralleled while the K1 relay is energized but may be manually paralleled when the relay is deenergized

- When answering items 2-43 through 2-46 refer to figure 4-15 in your textbook.

2-43. The reference bias voltage for Q1 in the synchronizing monitor appears across
1. capacitor C1
2. resistor R2
3. resistor R6
4. Zener diode CR8

2-44. The phase difference circuit turns Q1 off by means of a
1. reverse bias voltage across CR10
2. reverse bias voltage across R6
3. base-to-emitter short caused by the conduction of CR9
4. base-to-emitter short caused by the conduction of CR10

2-45. The voltage difference circuit turns Q1 off by means of a
1. reverse bias voltage across Q5
2. reverse bias voltage across R19
3. base-to-emitter short caused by the conduction of CR18
4. base-to-emitter short caused by the conduction of Q5

2-46. Q2 is controlled by
1. the phase difference circuit
2. the frequency difference circuit
3. simultaneous action of the voltage difference circuit and the frequency difference circuit
4. either the voltage difference circuit or the phase difference circuit

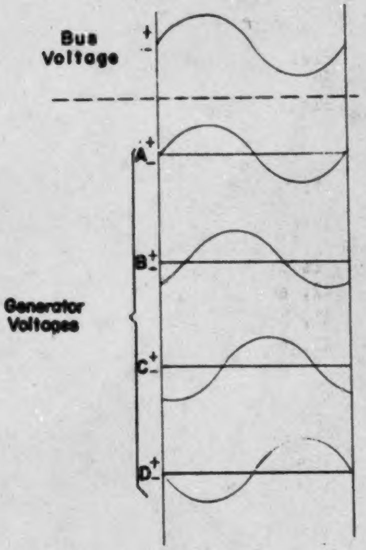

Figure 2A

2-47. Refer to figure 2A. Which generator voltage occurring simultaneously with the indicated bus voltage will produce the maximum current flow in CR10 in the phase difference monitoring circuit of the synchronizing monitor?
1. A
2. B
3. C
4. D

2-48. K1 relay will NOT close if the voltage difference in the generators is more than
1. 5%
2. 2%
3. 3%
4. 4%

2-49. What is the purpose of R19 in figure 4-21 of the textbook?
1. To prevent large voltage variations
2. To deenergize relay K1
3. To ensure that Q5 will remain off when relay K1 is deenergized
4. To ensure that Q5 will remain off when K1 is energized

2-50. Refer to figure 4-21 of your textbook. The difference in the magnitude of the sensing signals from the oncoming generator and the bus is detected in bridge circuit
1. CR15
2. CR16
3. CR17 (points A and B)
4. CR18

2-51. Which of the following components in the frequency difference monitoring circuit (figure 4-23 of the textbook) are connected in such a way that a beat frequency voltage is produced between the oncoming generator and the bus?
1. Primaries of T2 and T3
2. Secondaries of T2 and T3
3. Secondary of T2 and CR11
4. Transistors Q3 and Q4

2-52. Figure 4-24 of the textbook shows the results of various steps in the generation of a signal that is used to fire SCR1 in the frequency difference monitoring circuit. What is the purpose of the step that produces the waveform depicted by diagram E?
1. To produce a beat frequency voltage between the oncoming generator and the bus
2. To rectify and filter the beat frequency voltage
3. To assure that the clipped signal goes to zero when the original beat frequency voltage goes to zero
4. To assure that the clipped beat frequency signal maintains a constant d.c. level

2-53. Assume that a unijunction transistor has 0 volts on base 1 and 12 volts on base 2. If the transistor fires when the base 1-to-emitter voltage reaches 8 volts, the transistor has an eta value (intrinsic standoff ratio) of
1. 1/3
2. 1/2
3. 2/3
4. 4/3

To answer item 2-54 refer to figures 4-23, 4-25, and 4-26 of your textbook and assume that the difference in frequency between the oncoming generator voltage and the bus voltage is 0.2 hertz.

Hint: The time in seconds required for one full cycle (period) is found by dividing the time unit, one second, by the frequency, in hertz.

2-54. What is the time period for one cycle of the beat frequency voltage?
1. 0.5 seconds
2. 2.0 seconds
3. 2.5 seconds
4. 5.0 seconds

Learning Objective: Recognize fundamentals of servicing transistorized circuits. Textbook pages 74 and 75.

2-55. High-power transistors that are noticeably hot while operating have been damaged beyond use.

2-56. What is the first connection you make when using a signal generator as a transistor tester?
1. Connect the powerline to an isolation transformer
2. Connect the chassis of the signal generator to ground
3. Connect the chassis of the signal generator to the chassis of the equipment to be tested
4. Connect line voltage to signal generator

2-57. Ohmmeters will damage transistors if the meters are used in a range greater than
1. 0.25 ma
2. 0.50 ma
3. 0.75 ma
4. 1.00 ma

Learning Objective: Recognize operating principles of the switching and control circuits in the degaussing switchboard of the SSM Automatic Degaussing System. Textbook pages 76 through 80.

2-58. What circuit or coil in the SSM automatic degaussing system receives the gyro signal?
1. Remote control circuit
2. FI-QI degaussing coil
3. M degaussing coil
4. Control circuits

2-59. In the SSM Automatic Degaussing Control System, which coil channels are manually controlled?
1. M and A coil channels
2. A and FQ-QP coil channels
3. A and FI-QI coil channels
4. M and FP-QP coil channels

2-60. Control power for the manual coil channel control circuits is supplied by
1. the secondary of a common power transformer
2. the secondary of a separate power transformer
3. a d.c. power source
4. a ship's service lighting generator

2-61. The gyrocompass signal is a true heading signal. It is modified by the magnetic variation to obtain the magnetic heading signal used to compute the
1. necessary degaussing currents
2. FP-QP power supply
3. M-coil power supply
4. H-zone setting

2-62. The gear train, H-zone circuit, and the magnetic variation circuits of the computer drawer are independent control circuits of the A coil and FI-QI coil channels.

2-63. The maximum control signal or gain of the control circuit in the SSM Automatic Control Degaussing System is set by the
1. voltage divider
2. demodulator converter
3. a.c. signal of the resolver
4. d.c. signal from the H-zone circuit

2-64. In which of the following coil channels does a separate perm circuit apply a manually set d.c. signal to the operational amplifier input?
1. A
2. M
3. FP-QP
4. FI-QI

Learning Objective: Point out operating principles of the power supply and functions of components in the degaussing remote control unit of the SSM Automatic Degaussing System. Textbook pages 80 through 83.

2-65. Which amplifier, connected through reversing contacts on the pilot relay, presents a constant polarity signal to the inputs of the circuit?
1. Single-ended mixer amplifier
2. Switching amplifier
3. Excess error amplifier
4. Each of the above

2-66. The magnitude of the full-wave rectified signal produced by the mixer amplifier is modified by the
1. current feedback from the output circuit
2. voltage feedback of the output circuit
3. current feedback from the input circuit
4. voltage feedback from the input circuit

2-67. How many pairs of silicon controlled rectifiers (SCR) are in the power state circuit of the SSM Automatic Degaussing System?
1. Three
2. Four
3. Five
4. Six

2-68. Current through the primary windings of the 3-phase transformer in the power stage circuit is controlled by the
1. control transformer in the first stage
2. SCR's in the driver circuit
3. excess error amplifier
4. switching amplifier

2-69. Which component determines when the secondary power is rectified, filtered, and connected to the degaussing coil in proper polarity?
1. Switching amplifier
2. Excess error amplifier
3. Reversing contactor
4. Pilot relay

2-70. In the degaussing remote control unit, what controls the FI-QI and A coils when the automatic coils are in manual operation mode?
1. Meter Selection Switch
2. Heading Switch
3. Ammeter
4. Each of the above

2-71. What is the purpose of the degaussing remote control unit in figure 5-7 of the textbook?
1. To monitor and control all degaussing coils
2. To monitor the A-coil only
3. To control the FI-QI coil only
4. To monitor and control the A and FI-QI coils

Learning Objectives: Identify maintenance practices for the SSM Automatic Degaussing System. Textbook pages 83 through 85.

In items 2-72 through 2-74 select from column B the safe practice to observe when maintaining the components in column A.

A. Components

2-72. Capacitors and RFI filters

2-73. Printed circuits and semiconductors

2-74. Drawers in the switchboards

B. Safe Practices

1. Remove carefully because of excessive weight
2. Do not attempt to repair; maintenance is at a depot level
3. Ground to prevent shock hazards
4. Connect power before testing

2-75. What is the best technique for troubleshooting the SSM Automatic Degaussing Control System?
1. Observation
2. Replacement
3. Logical method
4. Historical data

Assignment 3

Gyrocompasses

Textbook Assignment: Pages 86 through 116

Learning Objective: Indicate the principle of operation of a free gyroscope, and the added properties that make it north-seeking. Textbook pages 86 through 93.

3-1. What are the supporting rings of a gyroscope?
1. Gimbals
2. Planes
3. Superstructures
4. Axes

3-2. A gyroscope rotor has how many degrees of freedom?
1. One
2. Two
3. Three
4. Four

3-3. If the supporting frame of a gyroscope is tilted to the left, the rotor axle will
1. tilt to the left
2. tilt to the right
3. not change direction
4. point in the same direction as the supporting frame

3-4. How can you increase gyroscope rigidity?
1. By increasing the weight of the rotor
2. By increasing the concentration of rotor weight near the circumference
3. By increasing the rotor speed
4. By carrying out any of the above measures

3-5. A free-spinning gyroscope is aligned east and west at the equator. If viewed from space for a 12-hour period the gyroscope will appear to do which of the following?
1. Make one complete revolution
2. Make two complete revolutions
3. Make one-half of a revolution
4. Remain stationary

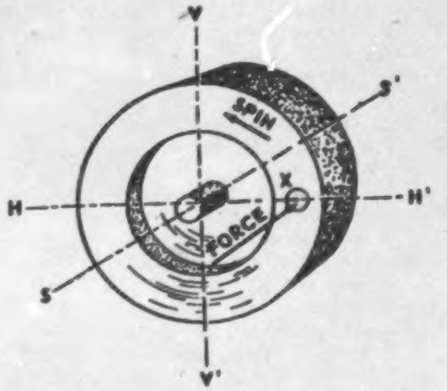

Figure 3A.—Gyroscope Rotor.

3-6. If a gyroscope spins in the direction shown in figure 3A, a force applied at X will cause
1. no precession
2. precession about the vertical axis, VV'
3. precession about the spinning axis, SS'
4. precession about the horizontal axis, HH'

3-7. A free-spinning gyroscope is aligned east and west at the equator. If viewed from the earth's surface for a 12-hour period, the gyroscope will appear to do which of the following?
1. Make one complete revolution
2. Make two complete revolutions
3. Make one-half revolution
4. Remain stationary

3-8. Horizontal earth rate is __(a)__ at __(b)__.
1. (a) Maximum; (b) Both poles
2. (a) Minimum; (b) Both poles
3. (a) Maximum; (b) Equator
4. (a) Minimum; (b) North pole only

3-9. To convert a gyroscope into a gyrocompass, it is necessary to
1. provide torques of the correct magnitude and direction
2. have the axis of spin of the gyroscope nearly level when parallel to the meridian
3. do both 1 and 2 above
4. provide two rotors

3-10. The mercury ballistic causes the Mk 11 gyrocompass to seek north by applying torque
1. to the horizontal axis
2. to the vertical axis
3. about the horizontal axis
4. about the vertical axis

- The offset point of connection is a fraction of an inch from the bottom center of the rotor case. Therefore, a small torque is introduced to dampen oscillations around the meridian.

3-11. What mechanical device(s) cause(s) the compass to be called a mechanical compass?
1. Ballistic
2. Offset point of connection
3. Both 1 and 2 above
4. Compensation weight

3-12. The Sperry Mk 19 gyrocompass employs which of the following to make it north-seeking?
1. The pendulous factor
2. Electronic control system
3. Both 1 and 2 above
4. Mercury ballistic

3-13. What causes the resistance to vary between the upper and lower electrodes of the electrolytic level?
1. The movement of the bubble
2. The movement of the potentiometer
3. The speed of the accelerometer
4. The movement of the mercury ballistic

3-14. The signal from the electrolytic level is amplified by the gravity reference system. Where is the amplified signal applied?
1. To the mercury ballistic
2. To the offset point of connection
3. To both 1 and 2 above
4. Through torques to the sensitive element

3-15. The mercury ballistic applies torque about the
1. spin and vertical axes
2. vertical axis
3. horizontal axis
4. horizontal and vertical axes

3-16. In the electrical/electronic compass dampening torque is obtained by applying a portion
1. of the gravity reference signal about the vertical axis
2. of the torque from the mercury ballistic about the vertical axis
3. of the gravity reference signal about the horizontal axis
4. of the torque from the mercury ballistic about the horizontal axis

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Learning Objective: Recognize characteristics, functions, and operating principles of the Mk 11 gyrocompass and its associated equipment. Textbook pages 92 through 101.

3-17. The Sperry Mk 11 gyrocompass is used principally on what type ship?
1. Cruiser
2. Aircraft carrier
3. Destroyer
4. Mine sweeper

3-18. Which of the following is NOT a part of the sensitive, or north-seeking element?
1. Vertical ring
2. Compensator weights
3. Binnacle
4. Follow-up indicator

3-19. The rotor of the Mk 11 Mod 6 gyrocompass rotates at a speed of 11,000 rpm in a vacuum of
1. 10 to 20 inches of mercury
2. 15 to 25 inches of mercury
3. 20 to 30 inches of mercury
4. 26 to 30 inches of mercury

3-20. When a gyrocompass is NOT running, the vertical ring should be locked in proper alignment so that the
1. suspension wire does not obtain a lasting set
2. gyro case cannot tilt about its horizontal axis
3. gyro rotor cannot tilt about its horizontal axis
4. suspension wire does not bear the weight of the mercury ballistic

3-21. The compensating weights are attached to the ___(a)___ and can be adjusted in the direction of ___(b)___.
1. (a) Phantom ring; (b) Rotor axis
2. (a) Vertical ring; (b) Rotor axis
3. (a) Vertical ring; (b) Vertical axis
4. (a) Phantom ring; (b) Vertical axis

3-22. The sensitive element is suspended from the phantom element by
1. small steel wires
2. two steel bars
3. a series of steel balls
4. a rubber coupling

3-23. The phantom element has north-seeking properties of its own.

3-24. Where are the mercury ballistic support bearings located?
1. On the vertical ring
2. On the gimbal ring
3. On the rotor case
4. On the phantom ring

3-25. The gravity-controlling force of the mercury ballistic acts upon the sensitive element of a gyrocompass through the
1. mercury reservoir
2. mercury ballistic frame
3. offset connection bearing
4. mercury ballistic solenoid

3-26. Which component of the gyrocompass supports the inner members of the master compass?
1. Phantom element
2. Suspension wire
3. Binnacle
4. Spider

3-27. The 120-volt, 3-phase 60-hertz power supply is designated as a secondary source of power for the compass.

3-28. If the primary source of power fails, the secondary source (the 24-VDC battery) will drive the motor generator. Where is the battery throwover relay found?
1. On the motor generator
2. On the compass control panel
3. On the bridge alarm indicator
4. On the IC switchboard

3-29. What is the purpose of the damping eliminator switch?
1. To restart the motor generator
2. To start the damping action of the mercury ballistic
3. To stop the damping action of the mercury ballistic
4. To stop the motor generator

3-30. The purpose of the followup system is to
1. detect any misalignment between the phantom and sensitive elements
2. drive the phantom element in the proper direction to restore alignment with the sensitive element
3. accomplish both 1 and 2 above
4. drive the sensitive element in the proper direction to restore alignment with the phantom element

3-31. The transmission system provides a means to transmit OSC readings to gyro repeaters at various stations on the ship.

3-32. The visual alarm for the transmitter overload relay is a red lamp. In the transmission system of the Sperry Mk 11 gyrocompass, what happens when a transmitter overload relay is energized?
1. The alarm lamp is energized
2. The alarm lamp is energized, and the transmitter rotor is deenergized
3. The alarm lamp is energized, and the transmitter stator is deenergized
4. The alarm lamp is energized, and both the transmitter rotor and stator are deenergized

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Learning Objective: Identify a Mk 19 gyrocompass, its associated equipment and functions. Textbook pages 102 through 113.

3-33. The Mk 19 gyrocompass is superior to all compasses preceding it because
1. it furnishes accurate heading data
2. it accurately measures and transmits angles of roll and pitch
3. of both 1 and 2 above
4. it is less expensive

3-34. One of the design features of the Mk 19 gyrocompass is that it
1. contains only one gyro
2. has two horizontally mounted gyros
3. has two vertically mounted gyros
4. has three horizontally mounted gyros

3-35. The slave gyro furnishes
1. heading information
2. heading and pitch information
3. heading and roll information
4. roll and pitch information

3-36. How are the meridian and slave gyro spheres suspended?
1. The meridian is suspended by steel wire; the slave is suspended in oil
2. The slave is suspended by wires from the meridian
3. The slave and meridian are both suspended in oil
4. The slave and meridian are both suspended by wires

3-37. Which of the following is/are included in the compass element?
1. Followup amplifier
2. Alarm system
3. Both 2 and 3 are correct
4. Phantom

3-38. Which of the following is/are included in the phantom assembly?
1. Sensitive element
2. Gimbals
3. Phantom
4. All of the above

3-39. Where are the roll and pitch synchro assemblies mounted?
1. Roll and pitch phantom
2. Azimuth phantom
3. Phantom element
4. Frame and binnacle

3-40. Which of the following units is NOT contained in the control cabinet of the Mk 19 gyrocompass?
1. D.C. power supply
2. Analog computer
3. Amplifier
4. Sensitive element

3-41. Where are the computer amplifiers mounted?
1. On the front of the control panel
2. On the rear of the control panel door
3. On the T-shaped panel
4. Behind the annunciator

3-42. The followup amplifiers are
1. type 1
2. type 2
3. type 3
4. identical and interchangeable

3-43. The regulated output voltage produced by the voltage regulator for the Mk 19 gyrocompass is accurate to
1. ±1 volt
2. ±0.75 volt
3. ±3 volts
4. ±0.02 volt

3-44. The compass failure annunciator for the Mk 19 Mod 3A gyrocompass is a visual and audible indicator.

3-45. The standby supply of the Mk 19 Mod 3A gyrocompass is a static supply.

3-46. All controls for the Mk 19 gyrocompass system are contained in
1. three major systems
2. three major systems and one minor system
3. four major systems
4. four major systems and one minor system

3-47. Which of the following signals is NOT an output of the gravity reference system?
1. Tangent latitude component
2. Meridian control signal
3. Damping signal
4. Compensated tilt signal

3-48. The output of the azimuth control amplifier is applied about the vertical axis of the slave gyro.

3-49. How many electrical degrees is the torque reference field displaced from the control field?
1. 45°
2. 90°
3. 120°
4. 180°

3-50. In figure 6-21C, the meridian gyro leveling control system has ___(a)___ input(s) and ___(b)___ output(s).
1. (a) one; (b) two
2. (a) two; (b) two
3. (a) two; (b) one
4. (a) three; (b) one

3-51. Compensation signals in the Mk 19 gyrocompass compensate for earth, ship and mechanical effects.

3-52. How is north-south drift compensated?
1. Manually
2. S sine C
3. S cos C
4. North-south acceleration computer

3-53. The latitude and tangent latitude computers compensate for earth rates.

3-54. Where is the azimuth pickoff for the azimuth followup system located?
1. On the gyro sphere
2. On the vertical ring
3. On the azimuth phantom
4. On the horizontal ring

3-55. Where is the meridian gyro roll-pitch pickoff located for the roll-pitch followup?
1. Gyro sphere
2. Meridian gyro cradle
3. Slave gyro cradle
4. Meridian vertical ring

3-56. What positions the roll-pitch synchro data transmitters?
1. Roll-pitch resolver
2. Roll-pitch phantom
3. Roll-pitch followup amplifiers
4. Roll-pitch followup motors

3-57. What actuates the alarms for the Mk 19 gyrocompass?
1. Above normal tube current
2. Normal tube current
3. Failure of tube current
4. Energizing the alarm relay

3-58. What is the purpose of the fast-settling system?
1. To reduce starting time
2. To level the gimbals
3. To eliminate damping
4. Each of the above is correct

Learning Objective: Describe records, logs, maintenance and operating procedures for all gyrocompass. Textbook pages 113 through 116.

3-59. The Gyro Service Record Book is a record of all work performed on the gyrocompass, including planned maintenance.

3-60. Who is responsible for the care and maintenance of the gyrocompass?
1. Navigator
2. Executive officer
3. Engineering officer
4. Each of the above

3-61. What is the greatest problem caused by neglected records?
1. False record of reliability
2. Incorrect dates
3. Inspections are neglected
4. Repairs are neglected

3-62. How does PQS help the Engineering officer obtain correct maintenance?
1. Ensures that watchstanders are qualified
2. Ensures that operators are qualified
3. Ensures that maintenance personnel are qualified
4. Each of the above is correct

3-63. Whenever the gyrocompass is started, the time must be entered in the Engineering log.

3-64. When is the standby compass made the master compass?
1. When the 20-2400 watch is relieved
2. When the end of the quarter is reached
3. When there is a casualty to the master compass
4. When the senior engineer of the watch designates a change is required

3-65. Who grants permission to secure the gyrocompass?
1. Commanding officer
2. Navigator
3. Chief Engineer
4. Engineering officer of the watch

Assignment 4

No Break Power Supplies; Electrohydraulic Load-Sensing Speed Governors; and Engineering Casualty Control

Textbook Assignment: Pages 117 through 162

Learning Objective: Recognize the characteristics of a no break power supply. Textbook pages 117 through 119.

4-1. What are the voltage and frequency low limits of a no break power supply?
1. 317 V 54 Hz
2. 315 V 54 Hz
3. 315 V 57 Hz
4. 317 V 57 Hz

4-2. What is the maximum time required for a no break power supply to return to the normal mode after normal power has been restored?
1. 1 sec
2. 2 sec
3. 1 min
4. 2 min

4-3. What is the tolerance range of the voltage regulator under high load and temperature variations?
1. 5%
2. 2%
3. 9%
4. 4%

Learning Objective: Recognize fundamentals of operation of a no break power supply. Textbook pages 117 through 125.

4-4. Under the normal operating condition, what is the supply-load in a no break power supply?
1. Emergency power supplies the a.c. motor; d.c. generator charges the battery
2. Ship's generators supply the a.c. motor; d.c. generator charges the battery
3. Battery supplies the d.c. motor; a.c. generator supplies the critical loads
4. Emergency power supplies the a.c. motor; d.c. generator supplies the critical load

4-5. What event takes place if the input voltage becomes higher than the reference voltage in the error voltage detector circuit as shown in figure 7-3 of the textbook?
1. The voltage drops across R6
2. Q1 conducts more than Q2
3. Q2 conducts more than Q1
4. The power supply will shift to the stop-gap mode

4-6. What happens to capacitor C4 when the voltage peaks at the unijunction transistor Q4?
1. C4 will short
2. C4 will open
3. C4 will charge
4. C4 will discharge

4-7. Refer to figure 7-6 of the textbook. How do SCR's accomplish power control?
1. By varying the voltage of the trigger pulse
2. By varying the conducting time of the gate pulse
3. By varying the trigger time on each half cycle
4. By varying the conducting angle

4-8. The average power output of the generator field rectifier can be varied by delaying the gate pulse from zero to nearly 180° along the phase time axis of each half cycle.

Learning Objective: Point out maintenance and repair practices for a no break power supply. Textbook page 126.

4-9. What is the maximum allowable pressure to use in cleaning the no break power supply motor-generator with compressed air?
1. 10 psi
2. 20 psi
3. 30 psi
4. 40 psi

4-10. Which method can be used to dry the windings of a no break power supply motor-generator set whose insulation resistance is less than 1 megohm?
1. Blow warm air across the windings with a fan
2. Dry the windings in an oven at a temperature greater than 90° C
3. Circulate through the windings a low voltage current that exceeds 80% of full load rating
4. Each of the above

Learning Objective: Identify the principles of operation of a static inverter. Textbook pages 127 through 134.

4-11. The input voltage to the model 4345A static inverter, which develops 400-Hz 3-phase output, is
1. 220 VAC
2. 120 VAC
3. 120 VDC
4. 250 VDC

4-12. What components enable the inverter to convert a 2-phase input to 3-phase power?
1. Oscillator assembly
2. Variable pulse width generator
3. Scott T-connected transformers
4. Power stage

4-13. The reference frequency used in the 4345A static inverter control circuits is
1. 1600 Hz
2. 800 Hz
3. 400 Hz
4. 60 Hz

4-14. The width of the pulse received by the voltage error-sensing circuit from a VPWG is determined by which of the following?
1. The duration of time that the monostable multivibrator is in an unstable state
2. The level of conduction of the transistor in the modulating circuit
3. The discharge time of the capacitor in the modulating circuit
4. All of the above

4-15. Once the SCR has started conducting, the only way to stop conduction is to
1. remove the gate voltage
2. reverse the gate voltage
3. apply a slightly greater reverse negative anode to positive cathode voltage
4. apply a slightly greater reverse positive anode to negative cathode voltage

4-16. In textbook figure 7-11 the time frame that C2 discharges is determined when
1. Q2 stops conducting
2. CR2 starts conducting
3. Q4 stops conducting
4. CR4 stops conducting

4-17. When Q2 stops conducting, what action causes the induced voltage in the 6-7 winding to reverse polarity?
1. Sudden drop to zero of current in the 2-3 winding of T1
2. Gradual drop to zero of current in the 2-3 winding of T1
3. Sudden rise of current in the 2-3 winding of T1
4. Gradual rise of current in the 2-3 winding of T1

4-18. Refer to textbook figure 7-10. The output of the power stages is filtered to convert
1. a 400-Hz square wave to a sine wave
2. an 800-Hz square wave to a sine wave
3. a 400-Hz sine wave to a square wave
4. an 800-Hz sine wave to a square wave

4-19. Transients developed in the system are removed by the
1. filters
2. power stages
3. clippers
4. drivers

4-20. The presence of which d.c. signal in the synchronizing stage should enable the multivibrator to turn the static inverter off?
1. -30 V
2. -20 V
3. +10 V
4. +20 V

4-21. The time delay introduced by the B-voltage interlock in the synchronizing stage enables which circuit to reach a steady state before the static inverter is turned on?
1. Oscillator
2. Variable pulse width generator
3. Synchronizing
4. Each of the above

4-22. During the run mode the control circuits get their power from the
1. +30 VDC power supply
2. input d.c. power source
3. CA phase of the inverter
4. inverter d.c. input voltage

4-23. The duration of the ON time of the power stage is controlled by the
1. leading edge of waveform C
2. trailing edge of waveform C
3. leading edge of waveform P
4. trailing edge of waveform P

Learning Objective: Point out the functions of the general components of an electrohydraulic load-sensing governor. Textbook pages 135 through 141.

4-24. Which component correctly positions the steam valve or throttle in an electrohydraulic load-sensing governor?
1. Magnetic amplifier
2. Electrohydraulic actuator
3. Flyweight head assembly
4. Permanent magnet generator

4-25. An error signal is produced by which of the following circuits?
1. Speed signal circuit
2. Transistor amplifier circuit
3. Reference circuit
4. Frequency sensitive and reference circuit.

4-26. In figure 8-2 of the textbook, changes in load are detected before they appear as speed changes by the
1. EG-M control box
2. permanent magnet generator
3. load signal box
4. resistor box

4-27. What happens when the remote servo piston movement is stopped by the control box signal returning to its on-speed value?
1. The pressure differential dissipates on both sides of the buffer
2. The buffer spring returns the buffer piston to the normal position
3. The pilot valve remains centered until the turbine speed is adjusted
4. All the above events occur

4-28. Where is the reference voltage developed for the EG-M control box?
1. Speed setting potentiometer
2. EG-M control box
3. Permanent magnet alternator
4. Load signal circuit

Learning Objective: Recognize the fundamentals of operation of an electrohydraulic load-sensing governor. Textbook pages 135 through 144.

4-29. The proper load ratio for paralleled generators equipped with electrohydraulic load-sensing governors is obtained by
1. using load-measuring circuits in the governor
2. a circulating current, in the tie cable connecting the generators, acts in the transistor amplifier circuit
3. increasing or decreasing the amount of fuel supplied to the generator prime mover
4. each of the above

● In the text refer to figures 8-3, 8-4 and 8-5 for items 4-30 through 4-35.

4-30. The EG-R hydraulic actuator receives its operating oil from
1. one of its own oil sumps
2. the oil system for turbine control
3. the engineroom hydraulic system
4. a generator bearing oil pump

4-31. What quality of an electrohydraulic governor is enhanced by a temporary negative feedback signal?
1. Dependability
2. Stability
3. Reliability
4. Each of the above

4-32. What is the purpose of the grooves that surround the EG remote servo piston?
1. To smooth the movement of the piston by allowing oil pressure to equalize on both sides of the piston
2. To ensure that any leaks of pressurized oil from the servo come from a part of the hydraulic system that will do no harm
3. To allow a pressure differential to dissipate at the same rate that the electrical signal is reduced
4. To displace oil on either side of the piston to create a pressure differential on the upper side of the compensating land

4-33. What happens to the steam when the EG remote servo piston is forced upward?
1. It decreases
2. It increases
3. It oscillates
4. It remains steady

4-34. What happens to the supply oil of the EG-R hydraulic actuator when the unit is shut down?
1. Pressure increases through port A
2. Pressure increases through port E
3. Pressure decreases through port A
4. Pressure decreases through port E

4-35. If the speed section offers -10 volts and the reference section offers +10 volts, what voltage is applied to the amplifier section of the EG-M control box?
1. Zero volts
2. -10 volts
3. +10 volts
4. +20 volts

● When answering items 4-36 through 4-38 refer to figure 8-6 in the textbook.

4-36. What happens to decrease the potential at point B?
1. An increase in the current through R5
2. A decrease in the voltage drop through R5
3. An increase in the resistance of the speed setting potentiometer
4. A decrease in the potential at point A

4-37. How is the turbine affected if the control box is disconnected at point I?
1. It stops
2. It speeds up
3. It hunts excessively
4. It slows down

4-38. An open at point J of the control box will cause
1. the prime mover to stop
2. a loss in reliability
3. a loss in stabilization
4. the speed of the prime mover to increase

Items 4-39 through 4-41 refer to figure 8-9 of the textbook. Select from column B the function for the potentiometer in column A.

A. Potentiometer	B. Functions
4-39. Droop adjustment	1. Compensates for the difference in generator ratings and reactive loads
4-40. Load pulse adjustment	2. Changes the amplitude of the input signal
4-41. Gain adjustment	3. Compensates for the change in direction of the steam valve
	4. Applies a variable voltage to transformer T2

Learning Objective: Identify the operating parameters and greatest source of trouble with the electrohydraulic governor. Textbook pages 144 through 146.

4-42. What are the input voltage limits across the hydraulic actuator of a single operating unit?
1. +0.5 to -0.5 VDC
2. +5.0 to -0.5 VDC
3. +0.25 to -0.25 VDC
4. +2.5 to -2.5 VDC

4-43. What is the source of most of the troubles in the hydraulic actuator of a load-sensing governor?
1. Unit out of adjustment
2. Defective control box
3. Faulty actuator
4. Dirty hydraulic oil

Learning Objective: Point out fundamentals of engineering casualty control. Textbook pages 147 through 152.

4-44. Who is responsible for formulating engineering casualty procedures and instructions pertinent to the electrical plant installed aboard your class of ship?
1. Engineer officer
2. Commanding officer
3. Type commander
4. Squadron commander

4-45. The primary objective of engineering casualty control is to
1. minimize personnel casualties
2. minimize secondary damage to engineering equipment
3. maintain maximum reliability of engineering equipment
4. operate engineering equipment at maximum economy

4-46. Each of the following is a normal function of casualty control except
1. inspecting engineering equipment
2. operating engineering equipment
3. replacing a damaged part on engineering equipment to prevent further damage
4. overhauling completely a piece of engineering equipment

4-47. The restoration phase of casualty control is concerned with the minimization of operational damage to prevent secondary damage to vital machinery.

4-48. Continuous operation of equipment under casualty conditions is a responsibility of a ship's
1. operations officer
2. commanding officer
3. engineering officer
4. officer of the watch

4-49. Which of the following best describes engineering readiness condition 2 aboard a DD?
1. Boiler and turbine combinations in use; remaining boilers available within 8 hours
2. Two boilers in use; remaining boilers secured, but operational within 2 hours
3. Two boilers in use with the main plant split; remaining boilers boosted to assure readiness within 1 hour
4. Four boilers in use with the main plant split

4-50. Which of the following engineering conditions of readiness is concerned with obtaining the best fuel economy to conform with operational requirements?
1. Condition 1
2. Condition 2
3. Condition 3
4. Condition 4

4-51. A continuous training program along with effective personnel organization will ensure the application of prompt corrective action to an engineering casualty.

4-52. What is the primary means of communication between the engineer officer and the various watch teams during casualty control procedures?
1. Sound-powered telephones
2. A general announcing system
3. Messengers
4. Ship's service telephones

4-53. Assume that valves X, Y, and Z, must be opened to cross-connect main feed portside. Which of the following commands will be most effective in accomplishing the cross-connection?
1. "Portside, open all main and auxiliary feed valves."
2. "Cross-connect main feed port side."
3. "Portside, open valves X, Y, and Z."
4. "Open main and auxiliary feed valves X, Y, and Z, portside."

4-54. Who is responsible for marking the casualty control board located in the after engineroom?
1. Messenger from Repair 5
2. Engineer officer
3. 2JV talker
4. Duty MMC

4-55. Assume that a fire has made it necessary for all personnel to abandon the after fireroom. To whom do these personnel report for assignment to duty?
1. Damage control officer
2. Officer in charge of Repair 5
3. Officer of the watch
4. 2JV talker at the casualty control board at main engine control

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Learning Objective: Recognize fireroom, engineroom and propulsion plant casualties, and procedures for handling them. Textbook pages 154 through 157.

4-56. Assume that the 2JV talker receives the message, "Class B Fire, fireroom No. 1 portside under FOS pump 2." Then, the 2JV talker loses contact with the fireroom talker. What action must be taken immediately?
1. Engineroom No. 1 must be notified to steam on the auxiliary line
2. The bridge must be notified, and fireroom No. 1 must be secured from topside and adjacent spaces
3. Repair 5 must investigate the fireroom and aid personnel
4. The 2JV talker must attempt to reestablish communications with the fireroom and if this is not possible, he must notify the officer of the watch of the break in communications

4-57. During a casualty in the forward engineroom, when the 2JV circuit is damaged, who is responsible for rigging an emergency circuit?
1. Engineroom talker
2. Electrical repairman of Repair 5
3. Messenger of Repair 5
4. Repair 5 team assigned to the job

4-58. When a ship's speed is affected by an engineroom casualty, the engineer officer of the watch will immediately notify the
1. engineer officer
2. officer of the deck
3. executive officer
4. commanding officer

4-59. What is the most important single factor in efficient control of a fireroom casualty affecting engineroom operation?
1. Flow of information between affected spaces
2. Speed of corrective action
3. Safety of personnel
4. Speed in cross-connecting standby units

4-60. Which of the following actions should an Electrician's Mate take when the fireroom reports a boiler high water casualty during split plant operation?
1. Trip the ship's service generator circuit breaker
2. Close the a.c. and d.c. bus-ties
3. Do both of the above
4. Trip the ship's service turbogenerator

4-61. Which of the following procedures should the fireroom watch carry out if loss of fuel oil suction occurs?
1. Secure the burners and blowers and start the standby service pump with suction on the standby service tank
2. Secure the burners and blowers and start the standby service pump with suction on the regular service tank
3. Secure the burners, keep the blowers running, and start the standby service pump with suction on the standby service tank
4. Secure the burners, close all registers, keep the blowers running, and start the standby service pump with suction on the standby service tank

4-62. Assume that you are in charge of a fireroom team. Your men report to you that the burners are sputtering and the fuel-oil service pump is suddenly racing. What is the probable cause of the trouble?
1. The pump is airbound
2. The fuel oil pump has lost suction
3. The fuel-oil suction line is clogged
4. The fuel line is broken

4-63. What is the first corrective action you should take if one of a ship's two propulsion shafts begins to vibrate excessively?
1. Investigate the spring bearings
2. Slow the affected shaft
3. Stop and secure the affected shaft
4. Slow both shafts

4-64. While you are standing the engineroom watch, one of the turbines begins to vibrate. What should you do?
1. Reduce the engine speed and the superheat temperature
2. Increase the engine speed and reduce the superheat temperature
3. Stop the engine and notify the officer of the watch
4. Stop the engine and investigate to determine the cause

4-65. Assume that the shaft affected by low lubricating oil pressure is rotating at three-quarter fullpower speed. To stop the shaft, if steam is available, you should use
1. the astern throttle
2. the astern turbine
3. the jacking gear
4. either the astern throttle or turbine

Learning Objective: Recognize operating procedures under normal and emergency conditions of the ship's service electrical plant. Textbook pages 157 through 159.

4-66. Which of the following extinguishing agents is used for electrical fires?
1. CO_2
2. Chemical foam
3. Mechanical foam
4. Water fog

4-67. If the lube oil pressure to a ship's service turbogenerator is lost while operating split plant, the usual steps to be taken in securing the affected generator include
1. tripping the generator circuit breakers
2. maintaining oil pressure by means of a hand-operated lube oil pump
3. closing the a.c. and d.c. bus-ties and the generator turbine throttle valve
4. all of the above

4-68. It is not necessary to stop a propulsion generator to remove it from the line.

4-69. Assume that you are unable to operate the control transfer switch of a diesel electric d.c. drive. Which of the following conditions is the most likely cause?
1. Controllers in the STOP position
2. Excitation control switch in the OFF position
3. Excitation control switch in the ON position
4. All of the above

Learning Objective: Identify the purposes of the casualty power system and its components. Textbook pages 160 and 161.

4-70. The purpose of a casualty power system is to
1. provide lighting for the ship when the normal lighting fails
2. maintain a source of electrical supply for the most vital machinery needed to keep the ship afloat in case of damage
3. provide an electrical supply for making temporary repairs
4. provide an electrical supply when the ship's service generators fail

4-71. Although the casualty power system is designed to utilize portable cables, the system contains permanently installed risers and bulkhead terminals. The purpose of the risers is to
1. permit extension of circuits through decks without destroying the watertight integrity
2. prevent errors in making connections
3. make the system more flexible and simplify its application and operation
4. limit the loads to be connected

4-72. Which components of emergency switchboards feed casualty power to equipment?
1. Bus bars
2. Circuit breakers
3. Transformers
4. Casualty power riser terminals

Learning Objective: Point out the value of drill in casualty control training. Textbook pages 161 and 162.

4-73. Simulated casualty exercises are often rendered ineffective because of
1. the limitation of simulated casualties
2. the lack of personnel with battle experience
3. the use of dry runs
4. inadequate advance preparation

4-74. What is the most important requirement for personnel who participate in simulated engineering casualty control operations?
1. Expert knowledge of repair operations
2. Familiarity with personnel casualty procedures
3. Familiarity with battle conditions
4. Familiarity with normal operating procedures

4-75. Dry runs are essential in the training of new crews in casualty control because they permit the crew members to
1. become familiar with casualty control procedures without endangering the ship's equipment
2. take action as they would under actual casualty conditions
3. function under simulated realistic battle conditions
4. do all of the above

Assignment 5

Maintenance Administration and Visual Landing Aids

Textbook Pages 163 through 191

Learning Objective: Identify fundamentals of maintenance administration. Textbook pages 163 through 170.

5-1. Corrective maintenance consists of procedures that extend the effective life of equipment or give advance notice of impending troubles.

5-2. What is the main objective of shipboard preventive maintenance?
1. To repair or replace equipment periodically even though it shows no sign of wear
2. To prevent the breaking down, deteriorating, or malfunctioning of equipment
3. To analyze equipment failures to prevent recurrence
4. To correct equipment failures

5-3. To fulfill its main purpose, the 3-M System must result in
1. automatic updating of information on Maintenance Requirement Cards
2. self-starting and self-implementing maintenance schedules
3. increased operational readiness of ships
4. complete elimination of equipment failures

5-4. Which of the following is an important part a PO1 or CPO plays in making the 3-M system work aboard his ship?
1. Providing cure-alls for equipment disorders
2. Training lower rated men to use the system properly
3. Performing routine operating checks only when they are listed under the system as planned
4. Consulting the PMS Manual for the maximum maintenance action required to eliminate equipment failure

5-5. As part of the MDCS, the data collection center has the primary responsibility for
1. filing the MDCS documents and making them available upon request
2. cataloging the information contained on the MDCS documents
3. screening the MDCS documents for completeness and accuracy
4. doing all the above

5-6. In which of the following manuals will you find the codes that are used in reporting maintenance actions?
1. PMS Manual
2. EIC Manual
3. MDCS Manual
4. NavShips Technical Manual

● Items 5-7 and 5-8 are based on the following list of typical jobs done by the shipyard force during a regular overhaul:

A. Installing guided missile launchers and strengthing adjacent deck structures
B. Replacing corroded metal piping with newly authorized plastic piping
C. Replacing a worn turbine bearing
D. Rewiring the armatures of several electric motors

5-7. What jobs are classified as repairs?
1. A and B
2. A and C
3. B and D
4. C and D

5-8. Job A is classified as a NAVALT because this work causes a change in the
1. maker's design
2. ship's fighting ability
3. ship's displacement
4. shipyard overhaul budget

5-9. SHIPALT CVA223A--USS Forrestal CVA-59, indicates that the number of alterations approved for CVA's is
1. 23
2. 69
3. 223
4. 269

5-10. According to Navy Regulations, the period of time assigned a ship for uninterrupted accomplishment of work at a repair activity is the ship's
1. availability
2. technical availability
3. shipyard overhaul
4. upkeep period

5-11. A ship needs emergency repairs to the anchor windlass at a naval shipyard. If the ship must continue her mission, which availability classification will probably be assigned?
1. Voyage repairs
2. Technical availability
3. Regular overhaul
4. Upkeep period

5-12. Under which availability classification can a ship leave a searchlight for repair at a shipyard and have it forwarded to the ship's next port of call?
1. Interim overhaul
2. Technical availability
3. Restricted availability
4. Voyage repair

5-13. Generally, instructions to report for a 2-week upkeep period will come to your ship from the
1. Chief of Naval Operations
2. type commander
3. ship's commanding officer
4. repair activity command

5-14. As a group leader you should plan in advance with your division officer, the repairs to be performed by a repair ship during a 2-week upkeep period.

5-15. Who attends the arrival conference with repair ship personnel to discuss the ship's work requests submitted for a 2-week upkeep period?
1. Commanding officer
2. Executive officer
3. Commanding officer and engineer officer
4. Executive officer and engineer officer

5-16. Each repair item sent by the ship to a repair facility should be tagged and its serial number should be recorded for ready reference.

5-17. The Electric Shop at a naval shipyard is identified by the numerals
1. 06
2. 07
3. 51
4. 72

5-18. You will probably have some contact with the civilian personnel working at a naval shipyard. Which of the following shipyard civilians has the highest rating?
1. Superintendent I
2. Superintendent II
3. Group Superintendent
4. Foreman (Leadingman)

5-19. Assume you are the ship's supervisor and require a speedup in work on some equipment the shipyard has removed for repair. You will normally talk to the ship's progressman who is a
1. civilian from the production department
2. supervisor from the planning department
3. naval officer from the shipyard
4. Leadingman from shop 56

5-20. Weekly progress reports of the regular overhaul work being accomplished on commissioned naval vessels are sent to
1. the type commander
2. the Chief of Naval Operations
3. the NavSea System Command
4. all of the above

5-21. The petty officer whose name appears in the ship's inspector column of the Shipyard Overhaul Work Progress Chart is personally responsible for keeping the chart accurate and up-to-date.

5-22. One of the purposes of the dock trial is to ascertain whether overhauled machinery is ready for service.

5-23. Which of the following is a purpose of an engineering department administrative inspection?
1. Ensuring that all records are kept in an intelligent and sound manner
2. Ensuring that all hands are highly trained not only in their specialties but also in damage control
3. Ensuring that all equipment is in a state of readiness so that the ship can carry out her intended mission
4. Each of the above

5-24. Administrative inspections are usually divided into two categories--general or detailed. Which of the following items is part of the general inspection?
1. Condition of living spaces
2. Posting of the Watch, Quarter and Station Bill
3. Maintenance of Ship's Material History
4. Availability of ship's plans

5-25. An objective of the battle problem is to determine how well personnel are able to work as a team under simulated battle conditions.

5-26. The Board of Inspection and Survey conducts a shipboard material inspection to determine
1. the suitability of the ship for further service
2. needed repairs, alterations, and design changes
3. both 1 and 2 above
4. the methods and procedures used in organizing each shipboard department

5-27. Which of the following is a duty of the EM during an economy or full-power trial?
1. Sounding fuel oil tanks
2. Recording switchboard instrument readings
3. Observing condenser water injection and discharge temperatures
4. Maintaining proper engine speed

Learning Objective: Identify components of the Visual Landing Aids by their function. Textbook pages 171 through 191.

5-28. Why were Visual Landing Aids (VLA) developed?
1. To extend flight to night
2. To extend flight in foul weather
3. Both 1 and 2 are correct
4. To provide visual contact with the ship

5-29. What voltage is available to the homing beacon lamp?
1. 440
2. 230
3. 115
4. 32

5-30. The stabilized glide slope indicator (GSI) is essentially a servo loop.

5-31. What is the function of the gyro on the stabilized platform of the GSI?
1. To hold the platform stable by force
2. To provide heading information to the pilot
3. To furnish reference information to the servo loop
4. To stabilize the light beam

5-32. In the normal operating mode, where is the reference voltage changed from a.c. to d.c.?
1. Gyro demodulator
2. Stab-lock relay
3. Servo amplifier
4. LVDT demodulator

5-33. What does the amplified d.c. signal operate?
1. Hydraulic actuator
2. Servo valve
3. Servo pump
4. LVDT demodulator

5-34. In figure 11-9 of the text, if the stab-lock relay is operated, the leveling signal will
1. flow from the gyro through the relay
2. not flow from the LVDT through the relay
3. flow from the relay through the LVDT
4. flow from the LVDT through the relay

5-35. In figure 11-10 of the text, what generates the error voltage that determines the position of the stable platform?
1. Manual control pot
2. Error detector
3. LVDT
4. Amplifier

5-36. How many light dimmer controls are shown in figure 11-11 of the text?
1. One
2. Two
3. Three
4. Four

5-37. On the remote control panel, what does the standby lamp indicate?
1. That power is available to the main switch
2. That the main switch is energized
3. That the source light is energized
4. That the hydraulic fluid is up to operating temperature

5-38. At what pressure will the low pressure relay be closed?
1. 90 psi
2. 1200 psi
3. 1400 psi
4. 1400 psi ± 5%

5-39. The lamp house assembly of the GSI contains which of the following?
1. One lamp and two heaters
2. Three lamps and two heaters
3. Three lamps
4. Two heaters, a thermostat, and three lamps

5-40. What is the purpose of the cooling fan?
1. To cool the fresnel lens
2. To cool the light tunnel
3. To cool the temperature control section
4. To cool the lamp house assembly

5-41. How is the dimmer for the edge lights connected?
1. In series with a rheostat
2. The primary of the transformer is connected to a dimmer rheostat
3. The primary of the transformer is connected to a variable transformer
4. The secondary of the transformer is connected to a rheostat

5-42. In figure 11-17 of the text, how is the flash sequence for the line-up lights connected?
1. In series with the variable transformer
2. In series with the 115/6.5 volt transformer
3. Both 1 and 2 are correct
4. In parallel with the line-up lights

5-43. What color are the extended line-up lights?
1. Amber
2. White
3. Green
4. Red

5-44. Where are the vertical drop-line lights located?
1. Aft of the line-up lights
2. Forward of the line-up lights
3. Across from the touchdown light
4. Up from the forward end of the line-up lights

5-45. Where is the Master Control Panel of the wave off light (WOL) located?
1. In the flight control station
2. At the captain's bridge control station
3. At the remote control station on the boat deck
4. On the fantail

5-46. In figure 11-22 of the text, how many operating stations are shown for the WOL?
1. 5
2. 2
3. 3
4. 4

5-47. What is/are the purpose(s) of the three red HIFR lights?
1. To indicate ship's heading
2. To indicate height
3. Both 1 and 2 above are correct
4. To indicate helicopter's heading

5-48. Why can't the VERTREP lights and the line-up lights be lighted at the same time?
1. The transformer cannot carry the load
2. The two sets of lights are at right angles to each other
3. The switching arrangement prevents illuminating both sets of lights simultaneously
4. The fuses will prevent operating both circuits at once

5-49. The detector for the control circuit of the variable transformer receives
1. one a.c. and one d.c. signal
2. two a.c. signals
3. two d.c. signals
4. one d.c. signal

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